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SOME PROPERTIES OF A SOIL HAVING A HIGH PERCENTAGE OF REPLACEABLE POTASSIUM: FIELD AND LABORATORY STUDIES ON COMPARATIVE VALUE OF SOIL CONDITIONERS

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This manuscript is a report of research conducted as Arizona Project R. R. 369 which is a contributing project to Western Regional Project W-30 "Measurement, Evaluation, and Modification of Soil Structure". This research was supported in most part by federal regional funds.

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FIGURES*

*All figures will be found in back of book.

PLATES*

*All plates will be found in back of book.

INTRODUCTION

The soils of the irrigated valleys of the Southwest are largely alluvial, vary widely in texture, are generally stratified, and have been subject to frequent changes through erosion, stream overflow, torrential summer rains, and other formative agents. They are potentially fertile soils because transported soils are usually composed of surface layers of soil from eroded uplands.

The waters which transport suspended materials and other products of erosion also carry dissolved salts. In semi-arid regions, where evaporation exceeds rainfall, these salts are deposited in the soil during the process of formation. Seasonal wetting and drying of the soil causes a large percentage of the calcium to precipitate as relatively insoluble carbonate, while sodium, which forms few insoluble salts, remains in soluble form; hence, the alluvial soils contain widely varying quantities of $CaCo_3$ and soluble sodium salts.

Practically all soils undergo some type of structural deterioration when they are put under cultivation. Here in the Southwest, the structural change may be due to either chemical or physical agencies, depending on the quality of the irrigation water and tillage practice. The adverse chemical changes are those arising from the accumulation of soluble salts and adsorbed sodium, although in many cases these are present when the soil is first put under cultivation. Hilgard is chiefly responsible for the early concept of sodium carbonate being the principal salt causing impairment in soil structure and gypsum as the major soil conditioner for removal of sodium carbonate from such soils. The modern concept of impaired structure in alkali soils is attributed to investigations of Gedroiz, Hissink, De Sigmond, and Kelley on the base exchange properties of soils. Gypsum functions in the correction of this modern concept by replacing Na with Ca in the exchange complex. The base exchange property of clay had been known for many years before its importance in the behavior of alkali soils was recognized, and it was some years after this before the clay minerals were identified as crystalline.

Certain of the minerals which compose the soil mass are chemically reactive, and this is true also for the soluble salts. The chemical and physical properties of the mineral particles which compose the soil are greatly influenced by the chemical reactions between the minerals and the salts. The trend of these reactions determines whether the soil will be a porous friable mass or a highly dispersed compact mass. The fundamental chemical reactions in the transformation from porous to compact soil, or vice versa, are fairly well known, and the use of soil conditioners for reclamation of alkali soils is based on this knowledge.

Despite this understanding of the fundamentals, all soils do not respond uniformly to the application of these principles under field conditions. It may be a matter of stratification, the nature of the dominant minerals and their properties, or other factors peculiar to the type of soil. South of Gilbert, Arizona, there is an area of land which has certain characteristics that have not been previously studied to any great extent despite the fact that they are mentioned in literature on semi-arid soils. These characteristics are high replaceable potassium and magnesium in the presence of a marginal sodium percentage in the exchange complex, and a very low organic matter content. The soil in this area is classified as Cajon silt loam. It cracks and crusts badly on drying but breaks up rather readily into a dust. Sixteen acres of this land were leased to the Agricultural Experiment Station for a period of 5 years for the study reported here of soil conditioners.

Soils with high percentages of calcium and sodium are of frequent occurence while soils with high potassium and magnesium percentages occur less frequently. In soils where a high sodium percentage exists, good structure is rapidly restored, in most cases, by replacing the sodium with calcium, but not all cases. The reason for this is not entirely known, although it is known that thorough drying after treatment with gypsum is essential in many cases. The relative replacing power of the four common bases varies somewhat under field conditions because of the variation in concentration and composition of the soil solution, the kind of base or bases in the adsorption complex, and the type of soil mineral. The major exchange reactions are between calcium and sodium which are usually present in largest quantities in irrigation waters and the soil solution. Despite the fact that potassium and magnesium are rarely present in relatively large quantities in irrigation water or the soil solution, high percentages in the exchange complex are occasionally found.

SOIL CONDITIONERS

The term "soil structure" is frequently used in reference to the physical condition of the soil. The farmer's concept of soil structure is as a pattern or system of pores which regulate permeability. The materials employed in restoring an aggregated condition are therefore referred to as soil conditioners. Their value lies in their capacity to bind soil particles into aggregates, to reduce mechanically the clay and silt percentage in the soil mass, or their effect on the ratio between the adsorbed bases in the clay minerals. These three groups may be illustrated as follows:

A. One group includes the inert or semi-inert materials which function largely by reducing the clay and silt percentage. Among these are sand, diatomaceous earth, vermiculite, sawdust, peat moss, and other ligneous materials. They impart a certain degree of looseness to the soil when applied in adequate amount.

B. Another group includes chemical and mineral materials which react with the exchange complex such as gypsum, sulfur, sulfuric acid, iron sulfate, polysulfides, and others.

C. A third group includes the organic synthetic soil conditioners such as the polyelectrolytes and the detergents which may lower the surface tension of water.

OBJECTIVES

The investigation was designed to study:

1. The value of a selected number of soil conditioners for improving the physical and chemical properties of the soil.

2. Evaluate the relative effectiveness of different soil conditioners.

3. Laboratory tests for determining the effect of conditioners on aggregation.

4. The effect of soil conditioners on growth of crops.

5. The influence of sodium and potassium percentage in the exchange complex on soil properties and soil behavior.

IRRIGATION WATER

The water used to irrigate the experimental area is supplied by the Roosevelt Conservation District from the eastern canal. Nine samples of water were taken from this canal over a period of one year. They represent the water used to irrigate the experimental area during 1952. The chemical analyses of these water samples are given in Table 1.

Attempts have been made to predict the effect of irrigation water on the soil and to establish limits for certain constituents suitable for soils and crops. Among the factors which make this very difficult are drainage, soil texture, clay minerals, the changes which take place when the irrigation water becomes the soil solution, and the fluctuation in soil moisture percentage between the wilting percentage and water holding capacity. Principal consideration is given to the total soluble salts, sodium percentage, and the bicarbonate content relative to the divalent cations Ca and Mg. These are important because high salt content contributes to salt accumulation in the soil, sodium percentage to sodium adsorption by the clay minerals, and an unfavorable ratio of bicarbonate to calcium and magnesium contributes to residual sodium carbonate.

In Table 1 the nine water samples show a range of 0.8 to 1.9 m.mhos./cm. conductivity and 15.4 to 39.28 m.e. per liter soluble salts. The sodium percentage (Na/Ca+Mg+Na+K) varied between 16.5 and 49.4. The data on bicarbonate and the two divalent cations is extremely favorable, namely, the divalent cations are in great excess. These are very low bicarbonate waters. On the basis of the chemical analyses given in Table 1, the irrigation water used on this land is quite satisfactory. That is, one would not expect to find a high sodium or potassium percentage in the exchange complex if the soil is properly irrigated with this water. This is confirmed, at least for sodium, by the soil analysis given in Table 3 and other analyses to follow. There had been a salinity build-up at the time the field experiment was started due to evaporation and this accounts for the moderately high sodium percentage of the soil shown in Table 3. Further evidence of this is shown by the sodium to calcium ratio of 0.58, average for the nine water samples, compared to 2.4 for the sodium to calcium ratio in the saturation extract of the soil at the start of the experiment.

Table 1. - Analyses of water samples taken from Eastern Canal representing water delivered over a 12-month period to the experimental plots, m.e./liter, Na and K percentage, cond.m.mhos./cm.

Date Sampled	Total Sol.Salts	Cond.Sat.Ext. m.mhos./cm.	Bicarbonate HCO_3	Chloride Cl	Sulfate SO_4	Calcium Ca	Magnesium Mg	Sodium Na m.e.	Sodium Na %	Potassium K m.e.	Potassium K %
3-21-52	31.43	1.5	2.11	10.38	2.92	11.58	1.23	2.68	16.5	.56	3.5
4-7-52	16.29	0.8	2.80	4.06	1.15	3.74	1.48	2.70	32.6	.36	4.3
4-25-52	15.40	0.8	2.52	3.72	1.40	4.14	.66	2.96	37.5	.15	1.9
6-15-52	16.00	0.8	2.75	3.55	1.54	4.89	.66	2.48	30.4	.13	1.6
7-21-52	19.04	0.8	0.95	6.49	1.94	3.74	.90	4.96	49.4	.46	4.6
9-23-52	30.36	1.5	2.03	10.77	3.12	8.23	2.47	5.48	33.4	.26	1.6
10-25-52	39.28	1.9	3.16	12.58	3.75	9.74	3.13	6.74	34.0	.18	0.9
2-3-53	31.64	1.7	1.11	13.25	3.12	10.48	.82	2.78	19.8	.18	1.3
3-12-53	21.55	0.9	0.54	6.94	2.29	5.24	1.56	4.83	40.9	.15	1.3
Minimum	15.40	0.8	0.54	3.55	1.15	3.74	.66	2.48	16.5	.13	0.9
Maximum	39.28	1.9	3.16	13.25	3.75	11.58	3.13	6.74	49.4	.56	4.6

In addition to the water samples from the canal, eleven wells in the vicinity of the experimental area were sampled to determine the composition of the underground water in this locality. The analyses of these are given in Table 2, and the location of the wells with respect to the experimental area is given in Figure 1. The Na percentage varied between 17 and 63, the K percentage between 0.3 and 1.8, and the conductivity between 0.9 and 6.0 m.mhos./cm. The principal reason for analysing the well waters was to determine if they would show some relation to the high K percentage in the soil. The analyses failed to offer any explanation for this.

LOCATION OF EXPERIMENTAL AREA AND PREPARATION OF THE LAND

The experimental area is located $6\frac{1}{2}$ miles south of Gilbert and represents land that had been abandoned because of salinity and alkalinity.

The three major essentials in land reclamation are (a) good drainage, (b) a supply of good water, and (c) properly leveled land. If harmful quantities of adsorbed Na are present then either the irrigation water must have a high Ca percentage or some type of soil conditioner should be used to replace the adsorbed Na with Ca.

The replaceable Na in the soil may be expressed as percent of the total exchange capacity or as milliequivalents (m.e.) per 100 grams of soil. The critical Na percentage at which structural breakdown takes place may vary with the total exchange capacity of the soil, the type of clay mineral, and other factors. A Na percentage, in the exchange complex, of 10 to 15 (6) has been suggested as a reasonable Na percentage for separating critical and non-critical levels, alkaline and non-alkaline soil. This division is more or less tentative because the relation between the Na percentage and change in soil properties is not sharp. In the course of extensive studies on the reclamation of land which had been inundated with sea water, VanBeekom et al (20) found that trouble may be expected when the exchangeable Na exceeds 1 m.e. per 100 grams if the soil is in a desalinized state "it may be roughly stated that soil structure may be unfavorably influenced as soon as more than 5 percent of the exchangeable cations consist of Na" but "breakdown in structure is far more harmful on heavy soils than on light soils."

The chemical and mechanical analysis of a representative soil sample taken from the experimental area before starting the experiment is given in Table 3 together with the partial analyses of three additional samples.

This analysis shows that the soil has a marginal Na percentage, namely in the range of 10 to 15 percent. It has a very high K percentage in the exchange complex and also a high Mg percentage. Conductivity shows a salinity which is well above the safe level. The organic matter content is very low and the absence of this binding agent contributes to a single grain structure conducive to wind erosion when dry cultivated. The Na to Ca ratio in the saturation extract is conducive to a build-up of adsorbed Na in the clay minerals. On the basis of existing standards of comparison, this soil is classified as a saline-alkali type.

Table 2. - Analyses of water samples taken from wells adjacent to experimental area; m.e./liter, percent Na and K, cond. m.mhos/cm.; samples taken March 1954.

No.	Well Location	Total Sol.Salts	Cond.	Bicarbonate HCO_3	Chloride Cl	Sulfate SO_4	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Sodium Na%	Potassium K%	Well Depth (feet)	Lift
1	13¼ 3W	21.37	1.0	1.79	6.43	1.54	5.09	2.80	3.57	.15	31	1.2	748	211
2	14 3W	30.96	0.9	1.87	10.03	2.37	8.88	3.70	3.96	.15	24	0.9	900	222
3	15 ¼W	17.93	0.9	2.26	4.77	1.39	4.14	1.81	3.43	.13	36	1.4	1300	330
4	15 1½W	47.11	2.2	1.77	18.10	2.94	16.02	3.95	4.13	.20	17	0.8	800	290
5	15 2½W	59.83	3.0	1.70	23.69	3.29	20.31	4.03	6.61	.20	21	0.6	846	193
6	15 3½W	16.94	0.9	1.92	5.05	1.56	5.09	trace	3.17	.15	38	1.8	800	266
7	15¼ 2W	34.78	1.8	1.82	12.75	2.39	9.63	3.21	4.78	.20	27	1.1	471	243
8	15½ 1¼W	26.73	1.3	2.06	8.35	1.81	6.14	3.21	3.96	.20	30	1.5	750	---
9	15 3/4 3W	120.07	5.5	2.26	49.30	7.33	33.93	10.53	16.52	.20	27	0.3	300	140
10	16 4½W	100.61	5.0	2.26	40.16	7.91	30.24	7.81	12.13	.18	30	0.4	600	---
11	16½ 4W	141.70	6.0	2.91	53.02	10.24	39.87	10.20	25.26	.20	63	0.3	354	---
Minimum		16.94	0.9	1.70	4.77	1.39	5.09	trace	3.17	.13	17	0.3	300	140
Maximum		141.70	6.0	2.91	53.02	10.24	39.87	10.20	25.26	.25	63	1.8	1300	330

Table 3. - Chemical and mechanical analyses of soil from Gilbert Experimental Area

	Soil Number			
	1	2	3	4
pH paste	7.75			
pH 1:10	8.80			
Exchange capacity, m.e. 100 gms.	15.70	16.8	14.0	18.9
Exchange Na, m.e. 100 gms.	2.30	1.8	1.6	2.6
Exchangeable Na, percent	14.6	10.7	11.4	13.8
Exchangeable K, m.e. 100 gms.	5.6	4.6	5.7	7.4
Exchangeable K, percent	35.6	27.5	40.7	39.1
Exchangeable Mg, m.e. 100 gms.	4.5			
Exchangeable Mg, percent	28.7			
Exchangeable Ca, m.e. 100 gms.	3.3			
Exchangeable Ca, percent	21.1			
Cond. Sat. Ext., m.mhos./cm.	16.0			
Na/Ca ratio in sat. ext.	2.4			
Percent sand	46.0			
Percent silt	31.0			
Percent clay (.005 m.m.)	24.0			
Percent clay (.002 m.m.)	19.0			
Gypsum requirement, tons per acre-foot	3.5			
Organic matter, percent	0.2			

One of the hazards of irrigation agriculture is the change in chemical composition of the irrigation water as it becomes a part of the soil solution. Evaporation loss and uptake of water by the crop contribute to a progressive increase in concentration of Na in the soil solution unless an irrigation program, designed to prevent salt accumulation, is employed. This is essentially the nature of the problem as it existed in the experimental area when it was taken over.

The examination of the soil to a depth of 4 feet showed no evidence of a major drainage problem and there was no water table problem. Therefore, on the basis of the soil analysis given in Table 3, a first step in reclamation should involve leveling the land to accomplish two of the major essentials in reclamation, namely, leaching and drainage. On the basis of the water analyses given in Table 1, the favorable Na to Ca ratio indicates that the Na percentage in the soil can be reduced without the aid of a soil conditioner. However, the accumulation of salt, the development of an unfavorable Na to Ca ratio in the soil solution, and the moderately high Na and K percentages in the exchange complex suggested that a soil conditioner should hasten reclamation.

To start the experiment the entire 16 acres was bench leveled and divided into east and west halves. It was leveled to a slope of 5/100 feet per 100 feet, and each half was divided into nine borders which were 1250 feet long and 30 feet wide (0.7 acre). The soil in this area pipes badly and has a single grained structure when dry. When irrigated, it disperses badly and deposits a surface layer of silt and clay, during each irrigation, which forms a crust on drying. In order to overcome the continuous breaking of ditch banks, it was necessary to install a concrete-lined ditch the full length of the field and concrete pipe lines, with outlet valves, at the head of each border.

The condition of the area, before reclamation, is illustrated in Plate 1. The condition of several adjacent fields in the area is illustrated in Plates 2,3,4 and 5, showing the poor growth of sorghum, cotton, and oats on this soil.

When the leveling operation had been completed and borders set up, the land was subsoiled and then leached with 2.7 acre-inches of water on June 1, 1952. Penetration of water was quite satisfactory at this time, probably due to the high salinity and the loosening of the surface soil. A second leaching was made with 1.8 acre-inches per acre on August 8, 1952 and penetration was very slow. This indicated that a large percentage of the salt had been removed in the first leaching and that a surface layer of silt and clay had begun to form. The condition of the soil following the second leaching, that is crusting and cracking, is shown in Plate 6.

Due to the variability in texture, salinity, and percentage Na and K in the exchange complex, the penetration of water for the second leaching was not uniform. Six soil samples were taken at random and the analyses of these showed a variation of 1,900 to 5,990 p.p.m. total soluble salts in soil, as compared with an average over the entire area of 8,000 p.p.m. before the first application of water on June 1, 1952. Additional information on the salinity of the area was obtained by the analyses of soil samples from nearby fields of sorghum and cotton. One of these contained 49,500 p.p.m. and the other 45,000 p.p.m. total soluble salts. These samples were taken from bare spots shown in Plates 2 and 4.

The salinity analyses of soil samples from the experimental area showed that leveling and leaching are major steps in the reclamation of this type of soil, and the growth of crops, which will be presented later, further confirms the importance of land preparation.

After the second leaching, and before the application of the soil conditioners and planting, a series of soil samples was taken from each of the borders to a depth of four feet. Each foot sample was kept as a separate sample for future reference.

1952-1953 EXPERIMENT

Application of Conditioners

The soil conditioners were applied in September, 1952, as follows:

Gypsum 1 ton per acre	Calcium polysulfide 15 gals. per acre
Gypsum 5 tons per acre	Calcium polysulfide 40 gals. per acre
Sulfur 1 ton per acre	HPAN 0.05 percent of acre 6 inches of soil
Check, no treatment	PR-51 20 lbs. per acre

Calcium polysulfide is frequently referred to as soluble sulfur or lime sulfur and has been given the formula CaS_5; however, it contains some thiosulfate, sulfite, and sulfate. HPAN is Monsanto Chemical Company's synthetic polyelectrolyte hydrolyzed polymer of acrylonitrile. PR-51 is a sulfonated alcohol, a detergent which reduces the surface tension of water. The gypsum, sulfur, HPAN, and PR-51 were applied previously to renovating the land. The calcium polysulfide was applied in the irrigation water at the first irrigation after planting. Barley was planted over the whole area in October, 1952. The design of the experiment is given in Figure 2.

Periodical Soil Tests, 1953

In 1953, soil samples were taken from four of the borders for comparison with master samples taken in 1952 after the leveling had been completed and before application of soil conditioners. Both sets of samples were taken from the same location in each border. The exchange capacities and replaceable Na and K were determined and these are given in Table 4.

These data show that the gypsum and sulfur treatments had reduced the Na percentage in the exchange complex at this stage of the experiment, but there was no significant change in K percentage. The calcium polysulfide did not show any effect.

The early growth of barley showed a good stand over the whole area (see Plate 7) except in a few scattered spots where structure or salinity had influenced seedling emergence or growth. The barley was planted in October and in November it was making best growth in the plot treated with the polyelectrolyte HPAN. To study this difference, soil samples were taken on November 7 from the HPAN plot and from the check plot immediately adjacent to the HPAN plot in border #7. The analyses of these soil samples are given in Table 5.

These analyses show little or no change in Na percentage in the exchange complex for the soil to which HPAN was applied. The small reduction indicated was probably a result of the high calcium percentage in the irrigation water. HPAN increased the rate of capillary rise very materially. Capillary rise is usually slowest in clay soils and therefore aggregation should tend to increase it.

In view of the improvement in capillary rise shown in Table 5, further tests were conducted to determine particle size distribution of water stable aggregates, using the wet-sieving technique, and the modulus of rupture. These data are given in Tables 6 and 7, and include later tests made on the soil at periods of 1 month, 6 months, 10 months, 12 months, and 22 months after application of the conditioners. Aggregates of 0.1 mm. as well as those of 0.05 mm. were significantly greater for the soil treated with HPAN than for the soil treated with other conditioners or control. No significant difference was found in the water stable aggregates for gypsum, sulfur, calcium polysulfide, PR-51, and control soils. Lunt and Huberty found little or no evidence of increase in water infiltration rate in soils due to decreased surface tension of water treated with wetting agents, and PR-51 was one of the wetting agents they used (13).

The modulus of rupture tests were significantly lower for the soils treated with HPAN. In Table 6 it will be noted that the modulus of rupture increased quite consistently during the period covered by the soil tests, namely 22 months. Similarly, the percent of water stable aggregates decreased over this same period.

In Table 7, where a comparison of water stable aggregates at several depths in the soil is given, HPAN is shown to be most effective in the 0-3 inch and 3-6 inch depth.

In the early part of June, 1953, infiltration tests were made in the field, using 8-inch rings. Water was placed in these rings and readings made at intervals for 18 hours. The 1 and 4-hour readings are given in Table 8 as inches-per-hour. Infiltration rates were also determined on 3-inch Uhland core samples and these data are given in Table 9. Apparent specific gravity determinations were made on soils from these plots and these are given in Table 10.

The field intake of water was materially increased by HPAN and slightly improved by gypsum at the rate of 5 tons per acre at the 1-hour reading. Similar results were obtained on the Uhland core samples, namely, a significant increase for HPAN and a lesser increase from gypsum. HPAN reduced the apparent specific gravity of this soil.

Analysis of Barley Hay Samples

On January 24, 1953, samples of barley hay were taken from each of the nine borders in the east half of the area. These analyses are given in Table 11. One purpose in taking these samples was to examine the effect of the high K percentage in the soil on K percentage in plants. The sample marked "Peoria" was taken from a barley field near Peoria, Arizona, at about the same stage of growth, in order to have a sample of hay grown on soil containing less exchangeable K.

Table 4. Conductivity of sat.ext., exchange capacity, and Na and K percentage in soils, before and after application of conditioners and irrigation.

Treatment per acre	Date Sampled	Cond. sat.ext. m.mhos./cm.	Exch. Cap. m.e./100 gms.	Exch. Na percentage	Exch. K percentage
5 tons gypsum	Aug. '52	1.6	12.8	25.3	31.2
	Mar. '53	3.3	13.8	18.2	30.4
Check	Aug. '52	4.0	15.2	21.6	23.7
	Mar. '53	3.7	13.9	23.7	25.2
40 gal. cal. poly.	Aug. '52	2.2	13.4	18.2	32.8
	Mar. '53	5.3	12.7	18.8	34.6
1 ton sulfur	Aug. '52	2.8	15.9	24.6	23.9
	Mar. '53	4.6	16.5	17.6	22.4

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Table 5. Analyses of soil samples from HPAN plot compared with check samples - Nov. 7, 1953.

	Check	Check	HPAN
Mechanical analysis, hydrometer method			
Sand, percent	44.0	43.4	47.4
Silt, percent	32.6	36.2	36.2
Clay (.005mm.), percent	23.4	20.4	16.4
Replacement capacity, m.e./100 gms.	16.5	16.0	16.7
Replaceable Na, percentage	14.5	13.1	13.7
Cap. rise cm. 24 hrs.	13.4	28.3	44.9

Table 6. The influence of soil conditioners on the size distribution of water-stable aggregates and modulus of rupture; 0-6 in. depth samples

Material per Acre	Water-Stable Aggregates >0.015mm. %	Water-Stable Aggregates <0.05mm. %	Mod. Rupt. m. bars
Soils sampled 1 month after application			
Gypsum, 1 ton	5	10	802
Gypsum, 5 tons	5	13	817
Cal. Poly., 20 gals.	5	8	763
Cal. Poly., 40 gals.	6	12	872
Sulfur, 1 ton	4	7	520
PR-51, 20 lbs.	5	14	830
HPAN	79	77	75
Check, none	4	10	805
Soils sampled 6 months after application			
Gypsum, 1 ton	5	12	795
Gypsum, 5 tons	5	12	679
Cal. Poly., 20 gals.	5	11	732
Cal. Poly., 40 gals.	5	10	728
Sulfur, 1 ton	5	8	422
PR-51, 20 lbs.	5	12	692
HPAN	63	60	95
Check, none	4	10	825
Soils sampled 10 months after application			
HPAN	46	51	98
Check, none	7	17	832
Soils sampled 12 months after application			
HPAN	38	53	121
Check, none	7	15	840
Soils sampled 22 months after application			
HPAN	42	47	535
Check, none	16	18	922

Table 7. The distribution of water-stable aggregates at various depths, as influenced by length of time after adding HPAN; percent

Sampling Depth (inches)	36 Days Aggregates $\geq$0.105mm.	36 Days Aggregates $\leq$0.05mm.	300 Days Aggregates $\geq$0.105mm.	300 Days Aggregates $\leq$0.05mm.	370 Days Aggregates $\geq$0.105mm.	370 Days Aggregates $\leq$0.05mm.	665 Days Aggregates $\geq$0.105mm.	665 Days Aggregates $\leq$0.05mm.
			Sampling Time, days after application					
HPAN-treated soil								
0 - 3	85	79	56	47	56	51	47	43
3 - 6	65	61	60	59	34	30	45	43
6 - 9	15	21	28	38	30	35	30	36
9 - 12	8	17	12	22	7	8	16	18
Check soil, control								
0 - 6	7	16	7	16	4	8	10	25
6 - 12	7	16	6	18	3	7	12	16

Table 8. Rate of water intake in the field;*
inches per hour

HPAN	Check	Calcium Polysulfide 40 gals.	Calcium Polysulfide 20 gals.	Gypsum 5 tons	Gypsum 1 ton	Check
			Rate for first hour			
1.22	0.25	0.12	0.66	0.47	0.41	0.46
1.00	0.50	0.28	0.47	0.96	0.47	0.30
1.63	0.32	0.17	0.34	0.41	0.17	0.27
1.24	0.38	0.17	0.25	0.27	0.17	0.46
1.25	0.36	0.18	0.43	0.53	0.30	0.37
			Rate per hour after 4 hours			
0.89	0.13	0.15	0.35	0.28	0.27	0.30
1.07	0.30	0.13	0.24	0.41	0.40	0.23
0.91	0.17	0.19	0.19	0.33	0.17	0.28
0.83	0.17	0.13	0.19	0.19	0.27	0.40
0.92	0.19	0.15	0.24	0.24	0.28	0.30

*Tests made by Karl Harris

Table 9. Infiltration rates, 3-inch Uhland cores,*
inches per hour

HPAN	Check	Calcium Polysulfide		Gypsum		Sulfur	Check
		40 gals. p.a.	20 gals. p.a.	5 tons p.a.	1 ton p.a.	1 ton p.a.	
1.33	0.15	0.07	0.07	0.07	0.18	0.24	0.42
1.55	0.16	0.07	0.14	0.30	0.14	0.24	0.43
1.33	0.20	0.22	0.14	0.14	0.21	0.30	0.34
1.50	0.25	0.41	0.37	0.68	0.86	0.26	0.25
1.00	0.21	0.41	0.37	0.67	0.90	0.24	0.24
1.33	0.20	0.20	0.34	0.53	0.90	0.38	0.30
		0.38	0.42	0.50	0.39	0.24	0.27
		0.38	0.38	0.43	0.29	0.70	0.28
		0.41	0.18	0.80	0.90	0.30	0.29
1.31	0.19	0.27	0.27	0.43	0.57	0.28	0.31

*Tests made by Karl Harris

Table 10. Apparent specific gravity*

HPAN	Check	Calcium Polysulfide 40 gals.p.a.	Calcium Polysulfide 20 gals. p.a.	Gypsum 5 tons p.a.	Gypsum 1 ton p.a.	Sulfur 1 ton p.a.	Check
1.28	1.46	1.47	1.47	1.49	1.40	1.41	1.41
1.27	1.50	1.47	1.47	1.49	1.40	1.50	1.42
1.32	1.50	1.47	1.47	1.49	1.40	1.44	1.41
1.50	1.46	1.41	1.42	1.45	1.44	1.50	1.48
1.54	1.50	1.44	1.55	1.47	1.47	1.41	1.35
1.36	1.53	1.33	1.50	1.60	1.40	1.38	1.50
		1.43	1.52	1.36	1.47	1.41	1.51
		1.44	1.41	1.36	1.51	1.44	1.42
		1.43	1.45	1.47	1.54	1.50	1.61
1.38	1.50	1.43	1.47	1.47	1.47	1.44	1.45

*Tests made by Karl Harris

Table 11. Analyses of barley hay from experimental plots

	Nitrogen % N	Magnesium % Mg	Phosphorus % P	Calcium % Ca	Potassium % K	Sodium % Na
Peoria	2.77	.29	.33	.52	4.76	1.44
Gypsum, 1 ton per acre	3.02	.24	.30	.44	4.03	1.37
Gypsum, 5 tons per acre	3.18	.22	.28	.42	4.72	1.17
*Gypsum, 5 tons per acre	1.70	.20	.30	.45	3.00	0.37
*Check	1.70	.22	.28	.44	2.59	0.45
Check	2.97	.22	.31	.38	4.52	1.08
Cal. Poly. 20 gals. per acre	2.89	.20	.26	.38	4.30	1.06
Cal. Poly. 40 gals. per acre	3.17	.19	.31	.40	4.57	1.46
Check	2.65	.22	.30	.43	4.19	1.51
Check	4.01	.17	.27	.47	5.06	1.27
HPAN	4.08	.19	.27	.47	2.15	1.27
Check	3.53	.19	.29	.44	4.72	1.55
Sulfur, 1 ton per acre	3.28	.15	.33	.52	4.37	1.38

*These samples were taken from a sandy streak across the field where the plants were making poor growth.

There is a wide variation in the nitrogen percentage of the barley hay and this probably reflects the variation in the soil. No fertilizer was used on this crop but the analyses of the irrigation water showed the presence of nitrate nitrogen. The lowest nitrogen percentage was found in the barley grown in a sandy streak where moisture stress was in evidence between irrigations. The highest nitrogen percentage was found in the hay from the HPAN plot where the water-holding capacity of the soil was increased by the application of this polyelectrolyte. Potassium percentage was also low in the barley growing in the sandy streak, but it was lowest in the barley growing in the HPAN plot. In order to check this low K percentage, additional plant samples were taken six weeks later, from the HPAN plot, and analysed for potassium. These analyses showed that at this time the potassium percentage had increased and was equal to that for the samples from the other plots. The sodium percentage was lowest in the plants from the sandy streak, showing that salinity reduction was most effective where the soil was lighter. A comparison of the barley plants from the experimental plots and from the field near Peoria showed that the high potassium percentage in the soil did not produce any excessive uptake of potassium by the barley.

Barley Yields

The barley grain was harvested on May 21, 1953, and the yields in pounds of grain per acre are given in Table 12.

The yields from the east and west halves of the field are given separately because the condition of the soil in the west half was better than in the east half. There was a small increase in yield from the 5-ton-per-acre application of gypsum in both sections of the field.

There was not enough HPAN or PR-51 on hand to treat a whole border. In view of this, small plot tests were installed in border #7. The second check given in the table was taken in border #7. The barley yields from the HPAN, PR-51, and check treatments in border #7 were calculated from quadrats. The PR-51 had no apparent effect on the yield and there was no visible effect on the soil or on water penetration. The HPAN showed a very definite yield response and this was evident in the appearance of the plants throughout the period of growth and also in the friable surface crust.

The good yields of grain obtained from the check plots, those which were leached without the addition of a conditioner, show that this soil can be reclaimed by simple leveling and leaching. From the analyses of irrigation waters in Table 1, one would expect this to be true.

Soil moisture determinations were made at different intervals during the growth of the crop and these analyses showed a higher moisture percentage at all times in the soil treated with HPAN. The higher yield of grain from the HPAN treatment may have been due, in part, to less moisture stress.

Table 12. Yield of barley grain, experimental area; pounds per acre.

Treatment	Pounds
East half of field	
Check, leaching only	2,822
Gypsum, 5 tons per acre	2,960
Calcium polysulfide, 40 gals. per acre	2,760
HPAN	3,722
PR-51	3,103
Check, leaching only	3,213
West half of field	
Check, leaching only	3,213
Gypsum, 5 tons per acre	3,420
Calcium polysulfide, 40 gals. per acre	2,850
Sulfur, 1 ton per acre	2,910

Sorghum Yields

After the barley crop was harvested, the land was renovated and the straw residue incorporated in the soil. Double dwarf Sooner milo was planted July 3, 1953. During the period of seedling emergence there was a major difference between treatments. It was significantly best in the soil treated with HPAN. On the basis of the modulus of rupture tests given in Table 6, one would expect better emergence in the soil treated with HPAN.

The crop was harvested on December 16, 1953, and the following grain yields were obtained:

	Lbs. grain per acre
Gypsum, 1 ton per acre	1,890
Gypsum, 5 tons per acre	2,163
Calcium polysulfide, 40 gals. per acre	2,166
Calcium polysulfide, 20 gals. per acre	1,929
HPAN	3,689
Check, leached	1,816

Bird damage to the heads contributed some to the differences in yield of grain, but there is quite definitely an increase in yield from the HPAN treatment.

Soil Analyses - 1952-1953 Samples

At the start of the experiment in 1952, a set of master soil samples was taken for future comparison. These samples were taken to a depth of 4 feet, each foot separately. The sampling locations were marked and, after the sorghum crop had been harvested, the soils were resampled to examine the changes due to leaching and soil conditioners. There were 36 sets of samples, two sets for each border. The analyses of these are given in Table 13. The samples labeled "W" were taken at the west end of the border and the "E" samples from the east end where the irrigation water entered the borders and where water penetration was better.

Soluble sodium There was a reduction in soluble Na in practically all of the 1953 soil samples at all depths as compared with soluble Na in the 1952 samples. This is true for the borders that were leached as well as those to which soil conditioners were applied in addition to leaching. The soluble Na in the west half of the field, borders 10 to 16, was less than in the east half, borders 1 to 9. Also the Na in the lower end of the east half of the field, borders 1 to 9, was higher than the upper end where the irrigation water entered the border. This may be due, in part, to the fact that soil was moved from east to west in leveling.

Exchangeable sodium The changes in exchangeable Na are somewhat variable but in most part there is a reduction trend. The irrigation water used on this field has a favorable Na to Ca ratio and therefore, there obviously should have been some replacement of Na in all plots. Most of the reduction in Na percentage in the exchange complex was in the surface foot of soil.

Exchangeable potassium There was little or no change in exchangeable K during this first year. It is of particular interest that, while the replaceable K was high throughout the four-foot profile, it was definitely highest in the surface soil.

Conductivity of the Saturation Extract The conductivity of the saturation extract was extremely variable over the area and throughout the four feet of the profile. In the east half of the area, the salinity was very much higher than in the west half. This correlates with the growth of crops on this soil when the land was taken over for the experiment. In the east half of the area, the soil was moved from east to west in leveling and the greater conductivity of the saturation extract is in the direction of the transported soil. The salinity was quite effectively reduced during the first year in all nine of the borders in the east half of the field. The conductivity data for 1952 and 1953 give further evidence that leveling and leaching give complete reclamation as far as salinity is concerned.

Soluble calcium In most part, this soil appears to be well supplied with soluble calcium, particularly for the 1953 samples from the gypsum and sulfur treatments.

With reference to other observations: Leaching reduced the pH, salinity, soluble Na, and percentage soluble Ca in the first and second foot of soils. Five tons of gypsum per acre reduced the pH, increased the salinity and soluble calcium percentage in the surface foot and reduced the soluble and replaceable Na. There appears to be little difference between the control plots and the calcium polysulfide plots. Sulfur reduced soluble Na, replaceable Na, increased conductivity of the saturation extract, soluble Ca, and gave a slight reduction in pH.

Table 13. Analyses of soils taken in 1952 at start of reclamation, and in 1953, one year later.

Border No.	Depth	Exchange Cap. m.e./100 gms. 1952	Exchange Cap. m.e./100 gms. 1953	Water Sol. Na m.e./100 gms. 1952	Water Sol. Na m.e./100 gms. 1953	Exchange Na m.e./100 gms. 1952	Exchange Na m.e./100 gms. 1953	Exchange K m.e./100 gms. 1952	Exchange K m.e./100 gms. 1953	pH 1952	pH 1953	Saturation Extract Con. m.mhos/cm. 1952	Saturation Extract Con. m.mhos/cm. 1953	Saturation Extract Ca. m.e.per liter 1952	Saturation Extract Ca. m.e.per liter 1953
1 ton gypsum per acre															
1 W	1	13.5	13.3	2.7	1.2	1.5	1.0	5.5	5.3	7.85	7.75	11.5	5.3	24.0	10.7
	2	16.5	16.1	8.5	1.5	1.5	1.5	4.1	5.1	7.45	8.00	50.0	3.2	18.2	3.4
	3	16.0	16.7	4.1	2.6	2.9	2.1	6.0	4.2	7.90	8.20	13.0	2.9	17.0	1.6
	4	19.0	19.7	6.5	4.5	5.1	3.1	2.5	2.6	7.80	7.90	16.5	10.8	20.0	14.4
1 ton gypsum per acre															
1 E	1	11.5	10.6	0.9	1.2	1.2	1.4	3.8	3.3	8.25	8.20	1.9	2.3	1.1	22.0
	2	12.8	11.5	1.3	2.2	1.6	2.5	4.1	2.9	8.25	8.50	2.7	2.4	1.8	0.8
	3	12.4	11.2	2.2	2.2	2.3	2.8	1.8	2.5						
	4	11.4	10.5	2.1	2.3	2.2	2.4	1.2	1.8						
5 tons gypsum per acre															
2 W	1	12.9	13.1	1.6	1.2	1.6	0.6	4.4	5.2	8.20	7.80	3.0	6.5	1.8	22.8
	2	16.6	17.7	1.7	1.9	1.4	1.6	5.1	5.9	7.95	8.05	4.8	4.5	11.1	6.1
	3	16.3	17.5	2.5	2.6	0.7	2.0	5.5	5.8	7.80	8.00	8.2	7.4	17.0	10.0
	4	16.0	17.3	3.0	4.9	2.9	2.8	4.5	4.0	8.20	7.80	6.0	14.2	4.0	28.0
5 tons gypsum per acre															
2 E	1	13.7	11.1	1.9	1.5	2.2	1.1	3.3	3.5	8.45	7.95	2.6	5.0	0.9	10.2
	2	13.3	11.6	2.8	2.1	2.7	2.7	3.2	3.2	8.15	8.25	8.0	2.5	6.3	1.2
	3	12.2	11.4	3.9	2.9	2.4	2.2	1.9	2.9						
	4	13.3	11.4	3.1	2.4	1.0	3.3	1.6	2.5						
Check plot															
3 W	1	17.6	14.0	2.9	1.4	2.0	1.4	5.3	5.7	7.95	7.95	9.5	4.3	15.4	5.4
	2	20.9	20.7	5.6	2.2	2.1	2.5	4.6	6.0	7.75	8.20	24.0	3.8	62.5	2.5
	3	20.5	25.9	5.4	3.5	2.3	2.6	3.6	5.9	7.70	8.00	22.0	10.7	49.0	13.0
	4	28.2	33.0	8.2	7.9	3.5	3.9	2.5	4.4	7.70	7.90	25.5	23.0	44.0	33.7

Table 13 (continued)

Border No.	Depth	Exchange Cap. m.e./100 gms. 1952	1953	Water Sol. Na m.e./100 gms. 1952	1953	Exchange Na m.e./100 gms. 1952	1953	Exchange K m.e./100 gms. 1952	1953	pH 1952	1953	Saturation Extract Con. m.mhos/cm. 1952	1953	Saturation Extract Ca m.e. per liter 1952	1953
							Check plot								
3 E	1	15.1	12.6	2.7	2.0	2.5	1.5	3.4	3.5	8.10	8.15	6.0	3.0	3.8	2.8
	2	14.9	13.1	2.8	1.6	3.4	3.0	2.3	2.6	8.45	8.45	2.9	2.3	2.8	3.4
	3	13.5	11.4	3.2	2.3	3.0	2.1	1.4	1.8						
	4	14.9	11.5	2.5	2.5	1.7	2.5	1.3	1.2						
							Polysulfide, 20 gals. per acre								
4 W	1	13.0	14.7	1.4	1.7	1.5	1.4	6.0	5.6	8.15	7.90	3.7	5.2	4.6	6.7
	2	33.0	29.1	4.5	2.3	1.9	3.0	5.0	4.6	7.75	8.10	17.5	3.5	45.0	2.8
	3	35.3	24.6	4.0	3.1	1.8	2.7	3.7	3.7	7.60	8.10	24.5	4.6	79.0	4.9
	4	28.5	22.0	4.3	5.0	3.3	4.1	2.4	2.4	8.60	7.90	9.0	14.5	7.0	22.1
							Polysulfide, 20 gals. per acre								
4 E	1	14.5	12.3	2.8	1.1	2.6	1.4	3.4	3.4	8.15	8.10	6.8	2.4	4.3	2.4
	2	14.1	14.9	4.1	1.5	3.1	2.5	2.8	3.2	7.95	8.25	12.0	1.7	10.0	1.1
	3	13.9	12.7	6.2	2.0	2.7	2.5	2.9	2.4						
	4	13.8	14.1	9.1	2.2	2.0	2.5	2.2	1.9						
							Polysulfide, 40 gals. per acre								
5 W	1	16.0	11.2	2.4	2.2	2.0	1.8	4.9	4.5	8.35	7.95	3.4	5.7	1.8	6.9
	2	19.3	18.9	4.2	3.0	2.0	1.8	3.9	4.8	7.70	7.90	16.3	7.6	42.5	11.6
	3	15.5	16.4	3.1	3.4	1.4	2.1	2.2	3.1						
	4	16.2	15.7	2.0	4.6	1.0	1.7	1.2	1.6						
							Polysulfide, 40 gals. per acre								
5 E	1	12.9	12.9	1.2	1.8	1.0	1.8	4.7	3.2	8.10	8.20	2.7	3.0	2.6	1.6
	2	11.7	13.2	2.0	2.3	2.2	2.4	2.4	3.1	8.40	8.35	2.9	2.5	0.7	0.8
	3	11.8	13.5	1.9	3.2	2.2	3.0	3.3	2.6						
	4	11.3	12.2	1.8	4.0	2.2	2.5	3.1	2.1						

Table 13 (continued)

Border No.	Depth	Exchange Cap. m.e./100 gms. 1952	Exchange Cap. m.e./100 gms. 1953	Water Sol. Na m.e./100 gms. 1952	Water Sol. Na m.e./100 gms. 1953	Exchange Na m.e./100 gms. 1952	Exchange Na m.e./100 gms. 1953	Exchange K m.e./100 gms. 1952	Exchange K m.e./100 gms. 1953	pH 1952	pH 1953	Saturation Extract Con. m.mhos/cm. 1952	Saturation Extract Con. m.mhos/cm. 1953	Saturation Extract Ca m.e. per liter 1952	Saturation Extract Ca m.e. per liter 1953
						Check plot									
7 W	1	18.2	16.7	3.1	2.5	1.9	2.1	5.0	4.5	7.95	7.85	8.4	7.2	9.7	7.1
	2	19.1	17.8	4.1	3.1	1.7	2.3	4.2	4.7	7.70	7.95	17.5	7.0	4.9	7.5
	3	15.6	16.1	2.3	4.1	1.5	1.7	4.2	4.2						
	4	16.5	16.2	3.7	5.9	2.2	2.6	4.7	2.9						
						Check plot									
7 E	1	13.6	14.2	3.1	2.0	2.4	2.0	3.5	3.5	8.00	8.10	8.0	3.3	8.3	2.3
	2	13.9	16.0	3.0	2.2	2.4	3.0	2.3	2.8	7.90	8.25	8.0	2.5	9.6	0.9
	3	12.7	15.2	3.2	2.7	2.0	3.8	2.2	2.3						
	4	15.0	13.8	2.9	3.3	2.4	3.6	0.5	1.0						
						HPAN Polyelectrolyte									
7 HPAN	1		16.4		1.5		1.8		2.8		8.05		2.3	7.8	1.8
	2		18.2		2.0		2.7		2.2		8.25		2.3	9.2	1.0
	3		15.6		2.3		1.7		0.8						
	4		17.1		2.4		3.6		0.4						
						Check plot									
8 W	1	17.00	16.9	2.6	1.9	2.0	3.2	4.4	3.8	7.95	7.95	6.0	4.2	7.1	4.9
	2	16.7	16.9	2.4	2.7	1.3	2.0	3.4	4.7	7.60	8.05	12.7	4.8	37.4	3.7
	3	13.8	20.2	1.7	2.7	0.8	2.0	2.8	5.1						
	4	14.9	11.1	2.4	3.8	2.0	2.1	2.6	4.4						
						Sulfur, 1 ton per acre									
9 W	1	15.1	14.9	3.3	3.0	1.6	1.4	3.1	3.8	8.10	7.70	5.2	13.5	5.1	40.0
	2	16.2	20.1	5.2	4.3	---	1.7	4.1	3.4	7.60	7.75	25.0	13.3	62.7	30.1
	3	16.2	15.9	6.3	4.4	3.0	2.0	4.0	4.6						
	4	15.4	16.6	8.6	7.0	3.1	4.4	0.7	2.2						

Table 13 (continued)

Border No.	Depth	Exchange Cap. m.e./100 gms. 1952	1953	Water Sol. Na m.e./100 gms. 1952	1953	Exchange Na m.e./100 gms. 1952	1953	Exchange K m.e./100 gms. 1952	1953	pH 1952	1953	Saturation Extract Con. m.mhos/cm. 1952	1953	Saturation Extract Ca m.e. per liter 1952	1953
							Sulfur, 1 ton per acre								
9 E	1	14.6	14.2	2.9	2.0	2.3	1.3	1.9	3.2	8.25	7.54	3.6	8.8	3.1	27.8
	2	17.6	15.8	4.5	2.5	1.2	2.7	2.9	1.8	7.95	8.05	10.0	5.2	10.0	5.0
	3	14.9	16.5	8.1	3.1	2.7	2.8								
	4	18.6	16.2	7.6	5.0	2.6	2.2								
							Polysulfide, 20 gals. per acre								
10 W	1	15.0	14.3	3.8	2.0	1.1	1.5	4.4	4.4	7.75	7.60	19.0	8.2	62.0	18.0
	2	16.2	16.3	4.5	2.5	1.1	1.8	3.2	4.2	7.35	7.65	42.0	12.0	222.0	33.0
10 E	1	12.4	13.1	0.9	0.9	1.2	1.3	2.8	2.7	8.30	7.95	1.3	2.4	2.9	6.3
	2	15.6	15.7	2.0	1.6	2.1	1.8	1.8	2.4	8.25	8.10	2.2	2.2	2.0	3.1
							Polysulfide, 40 gals. per acre								
11 W	1	14.9	15.6	3.1	1.9	1.5	1.6	4.3	4.7	7.70	7.55	15.0	5.6	42.3	9.3
	2	16.5	15.4	3.5	1.9	1.9	1.3	5.0	3.9	7.60	7.35	21.2	5.2	59.5	10.3
11 E	1	18.0	15.6	2.6	2.0	3.0	2.2	4.4	3.1	8.40	8.10	3.9	3.1	1.5	4.0
	2	14.6	18.2	3.4	3.1	3.4	4.0	3.9	2.1	8.20	8.30	6.3	3.2	3.5	1.8
							Sulfur, 1 ton per acre								
12 W	1	14.3	15.2	2.7	1.5	1.8	1.6	4.0	4.1	7.80	7.80	13.8	9.0	34.7	26.8
	2	13.0	13.7	1.4	---	1.3	---	4.4	4.2	7.85	7.75	6.2	7.7	13.0	16.0
12 E	1	14.9	16.0	2.1	2.5	2.7	---	3.6	1.9	8.45	8.70	2.3	7.3	1.0	26.9
	2	21.0	20.8	3.9	5.1	5.8	7.8	2.9	1.0	8.40	7.75	8.4	11.8	2.0	27.3

Table 13 (continued)

Border No.	Depth	Exchange Cap. m.e./100 gms. 1952	1953	Water Sol. Na m.e./100 gms. 1952	1953	Exchange Na m.e./100 gms. 1952	1953	Exchange K m.e./100 gms. 1952	1953	pH 1952	1953	Saturation Extract Con. m.mhos/cm. 1952	1953	Saturation Extract Ca m.e./liter 1952	1953
Check plot															
13 W	1	13.6	15.3	2.3	2.6	1.3	1.6	3.7	4.3	7.70	7.70	14.9	10.5	47.5	26.0
	2	12.2	11.6	1.7	1.4	1.6	1.2	2.2	5.4	7.75	7.85	7.2	5.7	20.5	12.8
13 E	1	12.6	15.7	1.5	1.5	6.4	1.9	2.4	2.2	8.45	8.10	1.5	2.5	2.0	1.3
	2	17.2	15.6	2.5	2.5	2.3	3.3	1.8	1.2	8.00	8.20	6.4	3.2	15.0	3.5
Gypsum, 5 tons per acre															
14 W	1	22.4	19.0	3.2	3.1	1.6	1.0	5.1	4.0	7.80	7.70	13.6	11.7	33.5	16.0
	2	13.1	12.5	1.5	1.7	0.9	1.2	2.7	2.6	7.60	7.60	13.0	9.4	45.2	23.2
14 E	1	19.8	17.5	2.3	1.9	1.3	1.2	1.5	1.6	7.95	7.70	5.0	1.5	11.2	37.2
	2	17.1	21.5	2.8	2.9	1.3	1.7	0.9	0.6	7.90	7.90	7.0	6.0	22.2	16.3
Gypsum, 1 ton per acre															
15 W	1	20.2	22.8	3.8	3.1	1.3	1.4	4.6	4.6	7.70	7.70	19.2	14.0	62.0	38.0
	2	14.0	12.7	0.9	1.3	1.2	1.1	1.8	2.1	7.70	7.70	9.0	8.6	26.9	22.5
15 E	1	15.9	21.9	2.7	2.8	2.5	2.5	3.1	3.3	8.30	7.95	3.3	6.9	10.9	10.0
	2	17.1	20.5	4.5	5.0	4.7	3.3	1.2	1.3	8.20	8.00	7.7	5.6	34.5	10.6
Check plot															
16 W	1	21.2	28.5	3.2	3.4	1.3	0.2	3.5	4.8	7.60	7.80	20.0	8.8	70.0	19.0
	2	11.2	12.9	1.3	1.3	0.9	1.0	1.8	2.0	7.65	7.80	11.4	7.0	37.5	19.5
16 E	1	19.8	23.1	1.8	2.6	1.6	1.5	1.5	1.7	8.10	7.80	4.4	8.2	5.4	9.3
	2	19.8	17.3	2.7	2.6	3.7	2.0	0.5	0.6	8.05	7.95	5.0	46.0	5.4	9.1

Capillary Rise Capillary rise represents the height to which water will rise through a soil by film forces. It may be expressed as rate of rise over a given period or as total height of rise over a given period. It is greatly influenced by the percentage of clay, silt, and sand-size particles in the soil and is, therefore, an excellent test for aggregation. In general, the rate of rise is most rapid when silt-size particles predominate in the soil. The capillary rise test described by Gardner (9) was used throughout this study as an indicator of the soil conditioner effects. The test was made on all the samples taken in 1952 and 1953, 180 in all. The data obtained are given in Table 14 as cm. rise for a 24-hour period.

The soil smaples were taken from both the upper ("E" in Table 14) and lower ("W" in Table 14) ends of the nine east borders, numbers 1 to 9, and, in a similar manner, from the borders in the west half of the field, numbers 10 to 16. The rate of capillary rise is shown to be widely variable over the area, but, since the 1952 and 1953 samples were taken from the same location in all the borders, they should be comparable with each other.

The lowest rate of capillary rise, in the check plots, was found for the surface foot samples. In the field, the soil structure problem is most in evidence in the surface soil. The rate of capillary rise increases with the increase in depth of the soil samples. In other words, the capillary rise test shows that the soil structure problem in this area is quite definitely a surface soil problem.

For the east half of the field, HPAN produced the greatest increase in capillary rise; but, both the sulfur and the 5-ton gypsum application gave significant increases. The effect of the polysulfide was not conclusive. In the west half of the experimental area, borders 10 to 16, sulfur and gypsum gave significant increases and the polysulfide was again somewhat variable in its effect.

The capillary rise was greater for the surface foot soil samples from the upper end of the east half of the experimental area where the conductivity of the saturation extract and the exchangeable K in the soil were lowest. A major part of the surface soil was moved from this part of the experimental area when leveling the land.

RECAPITULATION

A recapitulation of the experiment up to this point suggested some changes in the approach to certain phases of the soil problem. The results obtained from leveling, leaching, and application of soil conditioners showed that salinity can be effectively reduced by leaching, with or without the aid of soil conditioners. While gypsum and sulfur increased the rate of water penetration and reduced the exchangeable sodium percentage in the soil, the sodium percentage does not appear to be a major growth-inhibiting factor. The major problem is one in which the soil disperses as the irrigation water stands in the borders, and when the water penetrates, it leaves a layer of silt and clay on the surface which increases in thickness with each irrigation. This dries to a hard crust and interferes with seedling emergence and water penetration. The field experiment showed that the

Table 14. Capillary rise of water in soils from Gilbert plots, cm. rise in 24 hours, for 1952 and 1953 soil samples.

Border No.	Depth	Cap. 1952	Rise 1953	Border No.	Depth	Cap. 1952	Rise 1953	Border No.	Depth	Cap. 1952	Rise 1953
1 W	1	22.1	17.1	7 W	1	14.9	11.5	12 W	1	12.0	17.1
	2	22.1	28.1		2	11.5	12.0		2	16.1	13.9
	3	24.0	28.1		3	19.0	22.1				
	4	25.0	31.8		4	23.0	31.0				
1 E	1	48.0	37.0	7 E	1	16.5	20.9	12 E	1	22.1	32.9
	2	31.0	35.0		2	23.0	26.9		2	12.0	20.9
	3	49.0	41.0		3	28.6	34.1				
	4	53.0	36.0		4	26.4	31.1				
2 W	1	11.1	26.9	7HPAN	1		48.0	13 W	1	13.9	12.0
	2	12.9	12.0		2		35.1		2	19.0	19.0
	3	16.1	24.9		3		43.0				
	4	14.9	26.9		4		25.9				
2 E	1	24.0	40.0	8 W	1	9.6	13.4	13 E	1	28.1	20.9
	2	31.0	35.0		2	13.4	10.6		2	31.9	22.1
	3	43.0	29.0		3	24.0	22.1				
	4	43.0	32.0		4	32.0	35.1				
3 W	1	10.1	14.9	9 W	1	12.5	32.8	14 W	1	12.0	25.9
	2	12.0	8.9		2	12.9	16.5		2	47.0	38.9
	3	16.6	23.0		3	14.4	22.1				
	4	24.0	30.0		4	25.0	25.9				
3 E	1	18.5	25.0	9 E	1	13.9	41.5	14 E	1	25.9	35.0
	2	20.8	34.0		2	22.1	30.0		2	36.0	29.0
	3	29.5	44.8		3	30.0	40.2				
	4	22.6	23.0		4	30.0	34.0				
4 W	1	18.0	13.0	10 W	1	15.6	12.9	15 W	1	19.0	14.9
	2	13.0	10.1		2	28.1	13.4		2	43.9	46.0
	3	17.1	14.9								
	4	20.0	28.8								
4 E	1	17.0	31.9	10 E	1	52.0	36.0	15 E	1	36.0	36.0
	2	19.0	31.0		2	22.1	35.1		2	21.1	25.9
	3	28.1	32.8								
	4	25.0	31.0								
5 W	1	8.9	11.5	11 W	1	14.9	11.1	16 W	1	17.0	37.0
	2	14.4	13.0		2	----	13.9		2	50.8	53.0
	3	22.6	22.1								
	4	29.1	28.9								
5 E	1	32.0	24.0	11 E	1	13.9	25.0	16 E	1	27.1	24.0
	2	44.8	33.2		2	18.0	25.0		2	31.9	24.0
	3	26.0	42.0								
	4	38.0	39.0								

tendency to crust is reduced by polyelectrolyte and to a lesser extent by gypsum and sulfur. The modulus of rupture of the soil in the crust (0-6 inches), from the gypsum plots, was lower than for the crust from the check borders, but the gypsum did not completely eliminate crusting. Aldrich, Parker and Chapman (2) made some studies on the effects of sodium nitrate on surface soil which are pertinent. There was a serious impairment of water penetration and, while the Na to Ca ratio in the exchange complex was reduced, the soil contained less than 1 m.e. of replaceable Na per 100 grams. The deterioration in soil structure was confined to the upper six inches of soil, and below this level there was no evidence of impairment in soil structure or water penetration. They say: "The striking deterioration in tree condition in the sodium nitrate plots serves to emphasize the great importance of this surface horizon. Actually, the bulk of the root system is found below this layer but both water and air must move freely through it; hence, no matter how favorable the root zone may be, the condition of the surface soil is vital." Huberty and Pillsbury (11) also found that impaired infiltration of water in potato fields in the San Joaquin Valley was confined, in the main, to the soil surface.

The barley and sorghum yields, obtained in 1952 and 1953 from the experimental area after leveling and leaching, were quite satisfactory, particularly since no commercial fertilizer was used. The importance of leveling and leaching is well illustrated by an examination of some adjoining land which was cropped to oats in 1953. Both emergence and growth were spotty, as shown in Plate 9. Samples of soil were taken from good and poor spots in this oat field and analyses of these are given in Table 15. These soil analyses show that where salinity was low there was a good crop of oats and where the salinity was high the soil was bare. This spotty salinity was present in the experimental area prior to leveling and leaching. In the oat field, as in the experimental area, salinity was a major growth limiting factor and leveling to obtain a greater uniformity of water penetration will restore the productive capacity of the land. It is particularly significant that the ratio of Na to Ca in the saturation extract of the soil representing good growth of oats is very favorable (1 to 1), and this is reflected in a lower Na percentage in the exchange complex. On the other hand, where salt was allowed to accumulate, the Na to Ca ratio was extremely unfavorable (17 to 1) for both the crop and the soil and this in turn was reflected in a high Na percentage but had no apparent effect on the K percentage. The adsorption of Na by the exchange complex can be controlled if the salinity of the soil is not permitted to increase by evaporation of water from the soil surface. This can be accomplished by mulching to reduce surface evaporation or by regulating the interval between irrigations. As will be shown later, this soil appears to be peculiar in that the ratio of capillary rise of water in proportion to infiltration rate is unusually high. This indicates that between irrigations the soil moisture will rise to the surface where it is lost by evaporation and thereby deposit salt in excess of the quantity of salt washed down by irrigation water.

Table 15. Analyses of soils from good and poor spots in oat field south of experimental plots

	Good	Poor
Con. Sat. Ext. m.mhos/cm.	1.8	50.0
Saturation percentage	47.0	47.0
Sodium, p.p.m. Na in sat. ext.	270.0	5350.0
Calcium, p.p.m. Ca in sat. ext.	267.0	314.0
Exchange capacity, m.e./100 gms.	15.5	17.0
Exchange Na, m.e./100 gms.	0.5	2.6
Sodium percentage	3.2	15.3
Exchange K, m.e./100 gms.	3.7	3.7
Potassium percentage	23.8	21.8
Capillary rise, cm. 24 hr.	16.5	24.9
Infiltration rate, ml. 24 hr.	64.8	84.0

REVISED EXPERIMENT - 1954

For starting this reclamation experiment, the plots were set up on a farm scale - namely, large borders. The soil analyses and the growth of the crops showed that removal of salinity by leaching gave effective reclamation. This type of experiment having served its purpose, a part of the area was set aside for redesigning the experiment so as to have smaller experimental plots, more replications, and a randomization of treatments. Two borders in the east half of the area were split by a cement-lined ditch installed for the full length of the field. The borders on each side of the ditch were divided into 36 plots, 24 feet x 27 feet (15/1000 acre), giving 72 plots in all (see Plates 10 and 11). These were divided into 4 replicated groups of 17 treatments in a randomized design. This design is illustrated in the accompanying diagram. Following are the treatments: sulfuric acid, at the rates of 110 and 220 gallons per acre; soylaid, 400 and 2,000 pounds per acre; calcium polysulfide, at the rates of 40 and 100 gallons per acre; manure, at the rates of 10 and 20 tons per acre; gypsum, at the rates of 1 and 5 tons per acre; sulfur, at the rate of 1 ton per acre; orzan, at the rate of 1 ton per acre; PR-51, at the rate of 40 pounds per acre; IBMA, at the rate of 0.05 percent per 6 inches of soil; 10 tons manure plus 5 tons gypsum; and 10 tons manure plus 1 ton sulfur.

Soulaid is a natural ligneous material which has a pH value of 3.7 and about 26 percent organic matter. Calcium polysulfide is sometimes called soluble sulfur. It has arbitrarily been given the formuly CaS_5 but it also contains some thiosulfate, sulfite, and sulfate. It contains 6 percent Ca and 23 percent S. Orzan is a sulfonated lignin compound which is soluble in water and is sold both as a dry powder and as a liquid. IBMA is a polyelectrolyte manufactured by Monsanto Chemical Company, and is a half ammonium salt, half amide, of maleic acid.

	Treat-ment No.	Plot No.	Plot No.	Treat-ment No.	
		REPLICATE D			
Sulfuric acid, 110 gals.	12	10	9	5	Manure, 20 tons
Soylaid, 400 lbs.	14	11	8	16	Orzan, 1,000 lbs.
Cal. Polysulfide, 40 gals.	2	12	7	11	PR-51, 40 lbs.
Manure, 10 tons; sulfur, 1 ton	9	13	6	18	Check
Manure, 10 tons; gypsum, 5 tons	8	14	5	15	Soylaid, 1 ton
Check	17	15	4	4	Manure, 10 tons
Cal. Polysulfide, 100 gals.	3	16	3	13	Sulfuric acid, 220 gals.
Gypsum, 1 ton	6	17	2	1	Sulfur, 1 ton
Gypsum, 5 tons	7	18	1	10	IBMA, 1,000 lbs.
		REPLICATE C			
Sulfur, 1 ton	1	10	9	11	PR-51, 40 lbs.
Check	17	11	8	3	Cal. Polysulfide, 100 gals.
Orzan, 1,000 lbs.	16	12	7	9	Manure 10 tons; sulfur 1 ton
IBMA, 1,000 lbs.	10	13	6	14	Soylaid, 400 lbs.
Sulfuric acid, 220 gals.	13	14	5	18	Check
Manure, 10 tons	4	15	4	12	Sulfuric acid, 110 gals.
Soylaid, 1 ton	15	16	3	2	Cal. Polysulfide, 40 gals.
Manure, 10 tons; gypsum, 5 tons	8	17	2	6	Gypsum, 1 ton
Manure, 20 tons	5	18	1	7	Gypsum, 5 tons
		REPLICATE B			
Soylaid, 400 lbs.	14	10	9	8	Manure, 10 tons; gypsum 5 tons
Cal. Polysulfide, 100 gals.	3	11	8	12	Sulfuric acid, 110 gals.
Soylaid, 1 ton	15	12	7	16	Orzan, 1,000 lbs.
Check	17	13	6	2	Cal. Polysulfide, 40 gals.
Sulfur, 1 ton	1	14	5	13	Sulfuric acid, 220 gals.
Manure, 10 tons; sulfur, 1 ton	9	15	4	4	Manure, 10 tons
Gypsum, 1 ton	6	16	3	5	Manure, 20 tons
IBMA, 1,000 lbs.	10	17	2	7	Gypsum, 5 tons
PR-51, 40 lbs.	11	18	1	18	Check
		REPLICATE A			
Sulfuric acid, 220 gals.	13	10	9	3	Cal. Polysulfide, 100 gals.
Manure, 10 tons; gypsum, 5 tons	8	11	8	14	Soylaid, 400 lbs.
Manure, 20 tons	5	12	7	18	Check
Gypsum, 5 tons	7	13	6	9	Manure, 10 tons; sulfur, 1 ton
Manure, 10 tons	4	14	5	1	Sulfur, 1 ton
Check	17	15	4	10	IBMA, 1,000 lbs.
Orzan, 1,000 lbs.	16	16	3	6	Gypsum, 1 ton
PR-51, 40 lbs.	11	17	2	2	Cal. Polysulfide, 40 gals.
Soylaid, 1 ton	15	18	1	12	Sulfuric acid, 110 gals.

Randomization of plots and treatments in
revised experiment - 1954

Sorghum Crop - 1954

The area was irrigated on March 16, 1954. The dry soil conditioners were applied April 16, the land disced and borders made surrounding each plot (see Plate 11), after which 5 inches of water were applied. On May 11, combine-type milo was planted in 38-inch rows at a depth of 4 inches and at the rate of 10 pounds seed per acre. Seedbed moisture was judged insufficient for germination in a number of plots that had dried out more rapidly than others, so a 5-inch irrigation was applied on May 16. This resulted in a rather severe surface crusting, as shown in Plates 12 and 13, and this undoubtedly interfered with germination and emergence in some plots. Since the May 16 irrigation followed planting by only 5 days, it is probable that poor penetration rate in the plots where the poorest structure existed and the water stood longer, also interfered with germination.

Water penetration For the irrigations on March 16, April 16, May 16, June 29, and July 13, the rate of water penetration was estimated by comparing the depth of standing water in each plot. These measurements were made 24 hours after the water was applied and volume of water was calculated from depth and area of plots. The data are given in Tables 16 and 17. Table 16 shows the gallons of standing water per plot for the above dates.

The March 16 irrigation data, in comparison with the other four dates, illustrates the principal problem character of this soil. Reference is made to the dispersion of clay and silt in the standing water and the deposition of these fractions on the surface to form a surface film of poor permeability and in the pores of the subsurface. The first irrigation after preparing the land showed rapid penetration in all 4 replicates with a few exceptions. With successive irrigations infiltration rate decreased regardless of treatment with the IBMA plots as an exception. This illustrates the progressive impairment in the surface structure with successive irrigations. Further evidence of the influence of the surface film on infiltration rate is shown in a comparison of the data for A and B replicates with C and D. In the leveling operation, surface soil was moved from A and B to C and D, and therefore, more of the dispersive surface soil is present in the two latter replicates. This is more clearly illustrated in Table 17, giving a summary of the effect of the conditioners on infiltration rate. A response in improved infiltration is shown for IBMA, sulfuric acid, gypsum, and sulfur. None of the other materials showed any evidence of improvement in water intake.

Seedling Emergence An important effect of surface crusting is the influence on seedling emergence through the crust. A plant population, or seedling emergence count, was made for each of the plots on June 10. The counts were made on the 6 center rows of each plot. Soil samples were taken on June 12 from each plot representing a 6-inch depth of soil. These soil samples were taken one month after planting so do not necessarily represent the soil salinity at planting date. The plant counts and conductivity of the saturation extracts of the soils are given in Table 18.

Table 16. Measurement of standing water in plots 24 hours after irrigation, estimated as gallons per plot.

Treatment per acre	A Replicate *March 16	April 16	May 16	June 29	July 13	B Replicate *March 16	April 16	May 16	June 29	July 13
1. Sulfur	0	0	0	0	0	0	0	0	0	0
2. Cal. poly. 40 gals.	0	0	0	0	0	0	0	0	0	0
3. Cal. poly. 100 gals.	0	0	0	0	0	0	0	20	20	370
4. Manure, 10 tons	0	0	140	40	10	0	0	0	0	0
5. Manure, 20 tons	0	0	0	0	0	0	0	0	0	0
6. Gypsum, 1 ton	0	0	0	0	0	0	0	0	0	0
7. Gypsum, 5 tons	0	0	0	0	0	0	0	0	0	0
8. Manure, 10 tons; gypsum, 5 tons	0	0	0	0	0	0	0	0	0	0
9. Manure, 10 tons; sulfur, 1 ton	0	0	0	0	0	0	0	0	0	0
10. IBMA	0	0	0	0	0	0	0	0	0	0
11. PR-51	0	0	0	0	0	0	0	0	0	0
12. Sulf. acid, 110 gals.	0	0	0	0	0	0	0	0	0	0
13. Sulf. acid, 220 gals.	0	0	0	0	0	0	0	0	0	0
14. Soylaid, 400 lbs.	0	0	0	0	0	0	0	400	280	410
15. Soylaid, 1 ton	0	0	0	0	0	0	0	40	20	160
16. Orzan	0	0	100	120	10	0	0	0	0	0
17. Check	0	0	140	120	15	0	0	40	10	80
18. Check	0	0	20	0	0	0	0	100	1	1

Treatment per acre	C Replicate *March 16	April 16	May 16	June 29	July 13	D Replicate *March 16	April 16	May 16	June 29	July 13
1. Sulfur	0	5	25	120	330	500	5	40	370	410
2. Cal. poly. 40 gals.	0	0	0	50	180	15	150	280	250	1025
3. Cal. poly. 100 gals.	100	5	20	280	820	0	50	160	330	800
4. Manure, 10 tons	3	40	160	370	820	180	60	140	210	820
5. Manure, 20 tons	0	0	0	300	615	750	40	140	390	820
6. Gypsum, 1 ton	0	0	0	0	0	5	5	0	275	615
7. Gypsum, 5 tons	0	0	0	0	0	40	30	60	330	820
8. Manure, 10 tons; gypsum, 5 tons	0	0	0	1	60	20	10	100	100	60
9. Manure, 10 tons; sulfur, 1 ton	150	0	10	120	180	5	5	60	30	0
10. IBMA	200	10	20	1	10	740	0	0	0	0
11. PR-51	180	10	30	280	615	360	100	280	210	700
12. Sulf. acid, 110 gals.	3	5	0	60	160	40	300	370	140	250
13. Sulf. acid, 220 gals.	3	5	0	20	180	5	10	10	30	370
14. Soylaid, 400 lbs.	20	0	60	400	820	5	160	370	140	1005
15. Soylaid, 1 ton	0	10	40	370	615	650	60	140	240	615
16. Orzan	1	40	140	650	870	800	140	280	350	820
17. Check	10	60	240	580	870	20	300	240	330	820
18. Check	3	5	0	160	200	20	5	120	210	820

*This irrigation prior to application of conditioners; conditioners applied just before April 16 irrigation.

Table 17. Summary of volume of water standing in plots 24 hours after irrigation; average of four irrigations on each replicate; gallons per plot.

Treatment per acre	Replicates A	B	C	D
1. Sulfur	0	0	120	206
2. Cal. poly. 40 gals.	0	0	57	426
3. Cal. poly. 100 gals.	0	102	281	335
4. Manure, 10 tons	42	0	348	308
5. Manure, 20 tons	0	0	229	348
6. Gypsum, 1 ton	0	0	0	224
7. Gypsum, 5 tons	0	0	0	308
8. Manure, 10 tons; gypsum, 5 tons	0	0	15	68
9. Manure, 10 tons; sulfur, 1 ton	0	0	78	24
10. IBMA	0	0	10	0
11. PR-51	0	0	234	322
12. Sulf. acid, 110 gals.	0	0	56	265
13. Sulf. acid, 220 gals.	0	0	51	105
14. Soylaid, 400 lbs.	0	272	320	424
15. Soylaid, 1 ton	0	55	259	264
16. Orzan	57	0	425	398
17. Check	69	32	438	422
18. Check	5	25	91	289

In general, there is some correlation between the conductivity of the saturation extract and plant population. The B replicate has a sandy streak running through it, and therefore, some of the plots in this replicate are in lighter soil than the others. This may explain the better average emergence in replicate B. The D replicate is the poorest group of plots and has the lowest plant population. The emergence data indicate that texture, structure, and salinity all contributed to seedling emergence. Replicate A was in general lowest in salinity, but below B in plant population.

All the treatments that improved water penetration tended to increase seedling emergence and plant population. A comparison of the data in Table 18 with the data in Table 17 show better seedling emergence in the plots where water penetration was most rapid.

The salinity in replicates C and D is almost twice that in A and B and this correlates with a lesser plant count. The largest plant population was present in the plots treated with IBMA, sulfuric acid, gypsum, and PR-51. The pronounced effect of IBMA on the surface soil is illustrated by comparison of plates 14 and 15.

Plates 16 and 17 are given to show the favorable effect of polyelectrolyte on the growth of sorghum. Plate 16 represents the residual effect (1954) of HPAN applied ahead of the barley crop in 1952 (larger plants in the HPAN plot). Plate 17 represents the growth of sorghum for the 1954 application of IBMA for the 1954 crop. Plate 17 compares height of plants in IBMA and sulfuric acid plots.

Table 18. Plant emergence count on June 10, and conductivity of saturation extract of soil; m.mhos/cm., plants/ 6 center rows each plot.

Treatment per acre	Replicate A		Replicate B		Replicate C		Replicate D		Average	
	Plants	Cond.	Plants	Cond.	Plants	Cond.	Plants	Cond.	Plants	Cond.
1. Sulfur	209	4.05	297	4.80	74	8.60	136	7.80	179	6.31
2. Cal. poly. 40 gals.	94	2.58	304	2.25	179	4.60	81	3.80	189	3.31
3. Cal. poly. 100 gals.	407	4.15	136	3.39	110	6.15	118	5.80	193	4.62
4. Manure, 10 tons	131	2.90	414	2.20	95	6.80	94	3.80	183	3.92
5. Manure, 20 tons	101	2.70	280	2.48	127	3.60	74	5.00	145	3.44
6. Gypsum, 1 ton	242	2.41	300	2.28	350	4.95	102	9.50	243	4.80
7. Gypsum, 5 tons	284	5.20	269	5.40	435	6.05	110	8.50	274	6.29
8. Manure, 10 tons; gypsum, 5 tons	302	5.00	523	4.60	79	8.80	113	7.30	254	6.42
9. Manure, 10 tons; sulfur, 1 ton	182	6.60	228	5.80	89	6.20	118	7.90	154	6.62
10. IBMA	275	1.99	311	2.49	267	7.90	337	5.40	297	4.44
11. PR-51	242	2.42	390	2.39	108	6.05	139	3.45	290	3.58
12. Sulf. acid, 110 gals.	242	2.80	594	3.52	167	6.30	210	8.20	303	5.20
13. Sulf. acid, 220 gals.	330	4.95	569	2.99	94	9.50	180	5.95	293	5.85
14. Soylaid, 400 lbs.	200	2.29	144	3.08	85	4.60	66	3.15	124	3.28
15. Soylaid, 1 ton	201	2.05	128	2.85	98	5.90	126	3.65	138	3.61
16. Orzan	114	2.95	330	3.06	85	8.60	130	6.00	165	5.15
17. Check	125	3.55	210	2.43	132	5.25	98	5.95	141	4.29
Average	217	3.45	319	3.33	151	6.40	131	5.95		

Periodical Soil Tests - 1954

Some chemical changes in the soil were studied during 1954 in order to examine the changes at this period. On May 25, 10 days after an irrigation and two weeks after the sorghum had been planted, and on July 6 and August 24, soil samples were taken from plots 5, 6, 7, 10, and 12 in replicate A. Each sample was a composite of 4 cores taken to a depth of 6 inches. The analyses of these are given in table 19. These samples compared sulfur, sulfur plus manure, sulfuric acid, manure, and check plots. Manure measurably increased the percentage of organic matter. Sulfur had been well oxidized at this stage as shown by the pH, calcium percentage, and conductivity of the saturation extract. Sulfuric acid had also reduced the pH and increased the calcium percentage. Manure had little effect on the pH or soluble Ca. The infiltration test made in the field showed that the rate was most rapid for the sulfur and sulfur-plus-manure plots while it was slowest in the check plot.

A group of plots in C replicate was sampled on July 6 and August 9. These analyses compared the effect of gypsum, calcium polysulfide, sulfuric acid and check plots. The analyses are given in Table 19.

Gypsum and sulfuric acid increased the Ca percentage in the saturation extract and reduced the pH. The soil in the C replicate is higher in organic matter than the A replicate largely because top soil was moved from A during the land leveling operation. Infiltration rate was most rapid in the gypsum and sulfuric acid plots, least in the check and calcium polysulfide plots, and was less in replicate C than in replicate A.

Another soil study was conducted by examining the soil changes represented by the period between April 28 and May 25. The preplant irrigation was made March 16, the conditioners and irrigation applied April 16, and the plots again irrigated on May 16. Soil samples were taken to a depth of 12 inches and each three inches of soil kept separate for analysis. Six cores per plot were composited to make each sample. The treatments sampled were 110 gallons sulfuric acid per acre, 40 gallons calcium polysulfide, 220 gallons sulfuric acid, 40 pounds PR-51, 1 ton soylaid. The analytical data are given in Table 20.

Sulfuric acid The effect of sulfuric acid on pH was confined to the surface 3 inches where there was a reduction in pH to 7.2. Accompanying this pH reduction, there was an increase in soluble salts, particularly calcium salts. In the second set of samples taken on May 25, there was a reduction in salinity and increase in pH. The heavier application of acid merely increased the changes noted for the smaller application.

Calcium polysulfide There was no effect on pH or salinity but a slight increase in soluble calcium in the surface 3-inch layer of soil.

PR-51 There was no change in pH, salinity, or soluble Ca from the application of this conditioner.

Soylaid This ligneous material did not produce any change in pH or salinity, although it has an acid reaction.

Table 19. Analyses of soil samples taken from plots in 1954.

Treatment per acre	Date Sampled	Con. Sat. Ext. m.mhos/cm.	pH paste	Ca percent of bases in sat. ext.	Percent organic matter in soil
		Samples from A Replicate			
1 ton sulfur	5 - 25	4.0	7.8	23	
	7 - 6	3.3	7.9	19	
	8 - 24	3.6	7.9	19	.31
10 tons manure	5 - 25	3.2	8.0	12	
1 ton sulfur	7 - 6	4.0	7.9	22	
	8 - 24	4.2	8.0	21	.51
Check	5 - 25	1.9	8.3	7	
	7 - 6	1.9	8.2	7	
	8 - 24	2.0	8.2	8	.27
220 gals. sulf. acid	5 - 25	5.0	7.9	24	
	7 - 6	1.8	8.1	15	
	8 - 24	2.1	7.9	20	.23
20 tons manure	5 - 25	2.7	8.1	9	
	7 - 6	3.0	8.1	10	
	8 - 24	3.5	8.2	11	.62
		Samples from C Replicate			
5 tons gypsum	7 - 6	4.2	7.8	59	
	8 - 9	2.8	7.8	47	.39
1 ton gypsum	7 - 6	3.1	8.0	25	
	8 - 9	2.4	7.9	25	.47
40 gals. cal. poly.	7 - 6	3.2	8.1	19	
	8 - 9	3.3	7.8	25	.53
110 gals. sulf. acid	7 - 6	5.0	7.9	36	
	8 - 9	3.9	7.8	31	.57
Check	7 - 6	5.0	8.0	21	
	8 - 9	4.2	7.9	19	.57

Table 20. Analyses of soil samples taken April 28 and May 25, 1954.

Treatment per acre	Sample Depth (inches)	pH paste 4/28	pH paste 5/25	Sat. Ext. Conductivity m.mhos/cm. 4/28	Sat. Ext. Conductivity m.mhos/cm. 5/25	Ca percent of bases in sat. ext. 4/28	Ca percent of bases in sat. ext. 5/25
110 gals. sulf. acid	0 - 3	7.2	7.9	5.3	1.8	54	25
	3 - 6	8.1	8.1	2.8	1.1	16	13
	6 - 9	8.0	8.2	2.8	1.9	16	11
	9 - 12	8.0	8.2	3.2	2.5	10	9
40 gals. cal. poly.	0 - 3	8.1	8.1	2.2	2.1	24	8
	3 - 6	8.2	8.4	1.9	1.3	12	6
	6 - 9	8.1	8.4	2.2	1.8	10	6
	9 - 12	8.0	8.3	4.0	2.6	15	4
220 gals. sulf. acid	0 - 3	6.9	7.7	6.0	3.5	58	33
	3 - 6	7.9	8.0	3.5	2.6	21	15
	6 - 9	8.1	8.0	3.8	3.2	14	10
	9 - 12	8.2	8.0	2.5	4.0	11	6
40 lbs. PR-51	0 - 3	8.1	8.1	3.2	2.2	9	10
	3 - 6	8.1	8.1	2.8	1.8	9	9
	6 - 9	7.9	8.0	3.7	2.2	6	8
	9 - 12	8.0	8.0	3.8	2.7	12	7
1 ton soylaid	0 - 3	8.0	7.9	2.3	2.2	16	14
	3 - 6	8.0	8.0	2.0	1.6	16	11
	6 - 9	7.9	8.0	2.0	2.0	13	10
	9 - 12	7.9	8.0	3.0	2.2	15	9

At this period in the progress of the experiment, the evidence showed gypsum, sulfur, sulfuric acid, and IBMA had effectively improved water penetration and seedling emergence and reduced the Na percentage in the exchange complex, but had little or no effect on the K or Mg percentage. IBMA is the only material which significantly reduced surface crusting and even this was not permanent.

Aggregation The effect of the conditioners on aggregation and modulus of rupture is shown in Table 21. The increase in water stable aggregates for the soil treatments in this field experiment, resulting from the incorporation of IBMA at the rate of 1,000 pounds per acre, was significantly greater than for all other materials. Aggregation was not increased significantly above that of the check soil, by manure alone, or in combination with gypsum or sulfur. This is mentioned because in one treatment, manure was added at the rate of 20 tons per acre.

Modulus of rupture values were significantly reduced by incorporation of IBMA in the soil. Sulfuric acid at the rate of 220 gallons per acre reduced the modulus of rupture significantly below that of the checks and other treatments. Manure plus gypsum, and 5 tons gypsum per acre, were slightly higher than the above mentioned conditioners, but showed some improvement when compared with calcium polysulfide, soylaid, orzan, and PR-51. These data are given in Table 21.

Sorghum Harvest - 1954

The sorghum crop was harvested in October. The yields were somewhat affected by seedling emergence, head size, bird damage, and also probably by the fact that no commercial fertilizer was used in this experiment. The analysis of the soil samples taken on May 25 showed a low nitrate nitrogen, but a good supply of available phosphate at this time. The grain yields are given in Table 22. The yields were too variable for statistical significance. The early advantage in vegetative growth that was apparent during the early stages of growth in some plots did not manifest itself later in head size. Fertilizer might have changed this, even though the irrigation water contained some nitrate nitrogen. The yields given in Table 22 are the mean of four replicates of each treatment. The per-acre yields in the four replicate groups were as follows:

A - 3,217 pounds
B - 3,767 pounds
C - 3,693 pounds
D - 2,959 pounds

Plate No. 20 shows the excellent stand of sorghum obtained.

Final Soil Samples After 1954 Sorghum Crop

After the sorghum had been harvested, soil samples were taken from all 72 plots. These samples represented the surface 0 to 2 inches, and the subsurface depth 2 to 12 inches. The samples were all ground to pass a 2mm. sieve and then analysed for soluble Na, replaceable Na, replacement capacity, infiltration rate, capillary rise, and modulus of rupture.

Table 21. The influence of various soil conditioners on aggregation and modulus of rupture.

Treatment per acre	Sampled 1 month after application			Sampled 5 months after application		
	Water stable aggregates		modulus	Water stable aggregates		modulus
	>0.105 %	<0.05 %	rupture m.bar	>0.105 %	<0.05 %	rupture m.bar
Gypsum, 1 ton	6	17	1461	9	20	1855
Gypsum, 5 tons	5	20	1312	8	21	1587
Cal. poly., 40 gals.	7	18	1681	7	18	1914
Cal. poly., 100 gals.	6	16	1381	6	17	1821
Sulfur, 1 ton	6	19	1336	7	22	1898
Sulf. acid, 110 gals.	6	18	1141	9	18	1477
Sulf. acid, 220 gals.	7	19	929**	7	24	1252*
IBMA, 1,000 lbs.	47**	59**	874**	25**	48**	1280*
Check	6	13	1651	6	21	1927
Manure, 10 tons	7	19	1471	7	24	1788
Manure, 20 tons	7	21	1578	11	28	1524
Manure, 10 ton; gypsum, 5 ton	9	28	1244	8	28	1449
Manure, 10 ton; sulfur, 1 ton	7	22	1230	9	26	1693
PR-51, 40 lbs.	8	8	1715	8	19	2048
Soylaid, 400 lbs.	7	7	1583	7	20	1981
Soylaid, 1 ton	6	6	1529	8	21	1768
Orzan, 1 ton	8	8	1510	8	23	1894
Check	16	15	1578	7	18	2134

*Significant **Highly significant

Table 22. Yield of grain sorghum as influenced by soil conditioners - 1954.

Treatment per acre	Lbs. grain* per acre	Treatment per acre	Lbs. grain* per acre
Gypsum, 1 ton	3444	Manure, 10 tons	3829
Gypsum, 5 tons	3416	Manure, 20 tons	2948
Cal. poly. 40 gals.	3640	Manure, 10 tons; gypsum, 5 tons	3595
Cal. poly. 100 gals.	3780	Manure, 10 tons; sulfur, 1 ton	3805
Sulfur, 1 ton	3193	PR-51, 40 lbs.	2953
Sulf. acid, 110 gals.	3506	Soylaid, 400 lbs.	3128
Sulf. acid, 220 gals.	3951	Soylaid, 1 ton	3289
IBMA, 1,000 lbs.	3734	Orzan, 1 ton	3145
Check, none	3151		

*Mean of 4 replicates

Capillary rise was determined by the method used by Gardner (9). The data are given in Table 23 and the average for the four replicates of each treatment in Figures 3 and 4. A significant improvement in capillary rise is shown for the IBMA, 220 gallons sulfuric acid, 5 tons gypsum, 1 ton sulfur, 20 tons manure, and the manure-gypsum and manure-sulfur combinations. The 40-gallon application of polysulfide shows a high average rate but this is due to high capillary rise for the A and B replicates.

Infiltration rate data are given in Table 24, and the averages of four treatments in the four replicated plots are given in Figures 3 and 4. The table shows the average for each treatment for each replicated group. The data are in agreement with the capillary rise data, namely, best improvement from IBMA, sulfuric acid, gypsum, and manure, and a lower rate for the soil in the C and D replicates than in the A and B replicates.

Modulus of rupture was determined for the 0 to 2-inch soil samples and these data are given in Table 25. The average for the four replicates, Firgure 3, shows a reduction for the soils from the plots treated with IBMA, sulfuric acid, gypsum, and manure. In all others, there was no definite effect from the application of these conditioners. Within the several replicates there was considerable variation, but the trends are indicated in the averages.

Moisture equivalent determinations are given in Table 26. This value is an excellent measure of soil texture and these determinations are presented primarily to show the variation in texture throughout the experimental area. There is no particular significance to the data other than to illustrate the wide variation in soil texture throughout the area, and particularly the lighter texture in replicate B. This textural variation may bear some relation to the yields and to the data obtained from the laboratory soil tests.

Table 23. Capillary rise, cm. 24 hours, soils from Gilbert plots - 1954.

Treatment per acre	0-2 inch samples Replicates A	B	C	D	2-12 inch samples Replicates A	B	C	D
IBMA	54.0	56.8	31.0	34.1	38.0	38.9	14.9	17.1
110 gals. sulf. acid	48.0	42.0	24.0	25.0	34.1	42.0	20.9	16.1
220 gals. sulf. acid	49.0	49.0	27.6	31.0	36.9	49.0	22.1	14.9
1 ton gypsum	38.8	36.9	31.9	19.5	21.6	30.9	30.2	11.1
5 tons gypsum	40.8	40.8	44.5	31.0	42.0	35.1	32.4	22.1
1 ton sulfur	41.8	41.8	35.1	34.1	33.6	45.2	41.1	23.1
10 tons manure	32.1	41.5	16.2	17.1	14.4	40.1	13.0	13.0
20 tons manure	39.0	41.2	28.1	24.0	35.6	32.8	15.6	12.0
10 tons manure; 5 tons gypsum	32.8	42.0	25.5	32.0	20.9	42.5	36.0	19.8
10 tons manure; 1 ton sulfur	39.8	40.8	30.0	28.1	33.3	48.0	25.0	16.6
40 gals. polysulfide	44.6	46.0	26.4	18.5	25.9	35.0	24.0	14.9
400 gals. polysulfide	35.1	29.1	15.1	22.6	25.6	23.1	12.5	12.0
400 lbs. soylaid	28.1	25.0	18.0	19.0	22.1	23.0	13.0	13.0
1 ton soylaid	44.2	27.0	13.4	19.8	36.4	18.0	12.0	11.0
1,000 lbs. orzan	32.0	43.0	14.9	18.0	19.0	39.0	10.6	9.6
40 lbs. PR-51	40.0	29.1	14.4	22.6	26.0	26.9	12.0	11.0
Check	28.8	30.0	16.1	14.9	16.1	16.6	12.5	12.0
Check	35.1	25.0	9.6	16.1	20.9	22.6	12.0	11.9
Average	39.1	38.1	23.4	23.7	27.8	32.6	20.0	14.5

Table 24. Infiltration rate ml. 24 hours, soils from Gilbert plots - 1954.

Treatment per acre	0-2 inch samples Replicates				2-12 inch samples Replicates			
	A	B	C	D	A	B	C	D
IBMA	1074	1310	221	259	391	250	190	134
110 gals. sulf. acid	511	358	139	154	341	420	221	77
220 gals. sulf. acid	571	624	276	336	384	684	175	101
1 ton gypsum	266	418	230	139	120	290	310	58
5 tons gypsum	305	430	355	214	290	331	281	146
1 ton sulfur	295	341	245	209	259	250	269	156
10 tons manure	204	427	86	70	101	379	65	55
20 tons manure	279	432	233	185	365	470	78	36
10 tons manure; 5 tons gypsum	403	389	161	319	110	290	281	166
10 tons manure; 1 ton sulfur	254	410	209	281	226	281	192	139
40 gals. polysulfide	312	401	161	137	175	235	199	45
400 gals. polysulfide	240	163	70	151	139	110	70	34
400 lbs. soylaid	264	130	113	137	156	110	125	41
1 ton soylaid	362	173	41	127	315	115	43	55
1,000 lbs. orzan	175	319	84	161	110	336	41	21
40 lbs. PR-51	314	408	79	178	180	200	50	19
Check	245	168	96	70	70	79	156	55
Check	187	204	65	144	110	161	41	36
Average	348	384	159	182	213	277	155	76

Table 25. Modulus of rupture, millibars;
soils from Gilbert plots;
0 to 2-inch samples.

Treatment per acre	Replicates A	B	C	D	Average
IBMA	614	599	1256	1319	947
110 gals. sulf. acid	1512	677	1213	1796	1299
220 gals. sulf. acid	866	1244	1115	1382	1152
1 ton gypsum	1292	1103	1040	1748	1296
5 tons gypsum	1270	1088	785	1270	1350
1 ton sulfur	1323	1166	1476	1413	1344
10 tons manure	1355	1103	1523	1523	1376
20 tons manure	1181	819	769	1302	1018
10 tons manure; 5 tons gypsum	1008	772	1209	1413	1100
10 tons manure; 1 ton sulfur	1166	866	1193	1670	1224
40 gals. polysulfide	1890	961	1197	1591	1410
100 gals. polysulfide	1197	1528	1601	1476	1450
400 lbs. soylaid	1339	1103	1335	2158	1484
1 ton soylaid	1244	1323	1554	1617	1434
1,000 lbs. orzan	1433	945	1711	2048	1534
40 lbs. PR-51	1008	1292	1696	1953	1487
Check	1134	1118	1227	1413	1348
Check		1260	1554	1523	1324
Average	1225	1054	1331	1600	

Table 26. Moisture equivalent; 1954 soil samples; percent.

Treatment per acre	Replicates A	B	C	D
Sulf. acid, 110 gals.	17.6	17.5	25.1	19.2
Cal. Poly., 40 gals.	17.7	16.7	23.2	18.2
Gypsum, 1 ton	20.2	18.0	21.0	19.6
IBMA, 1,000 lbs.	23.2	16.2	23.6	22.9
Sulfur, 1 ton	20.0	17.8	25.3	23.2
Manure, 10 tons; sulfur, 1 ton	20.4	19.3	27.7	19.4
Check	19.9	19.6	23.4	16.3
Soylaid, 400 lbs.	22.3	20.2	24.2	19.9
Cal. Poly., 100 gals.	15.3	20.6	24.9	19.8
Sulf. acid, 220 gals.	24.5	14.8	24.0	22.0
Manure, 10 tons; gypsum, 5 tons	17.3	20.8	21.7	16.1
Manure, 20 tons	21.4	15.4	22.9	21.3
Gypsum, 5 tons	19.7	18.1	18.9	20.9
Manure, 10 tons	25.6	14.7	23.0	21.2
Check	26.3	19.7	24.9	23.8
Orzan, 1 ton	25.8	16.0	23.3	19.9
PR-51, 40 lbs.	17.6	15.5	29.9	20.0
Soylaid, 1 ton	26.7	17.4	22.8	20.8
Average	21.2	17.7	23.9	20.3
Minimum	15.3	14.7	18.9	16.1
Maximum	26.7	20.8	29.9	23.8

Replaceable Na was determined in both the 0 to 2, and 2 to 12-inch soil samples from each plot in all four replicates. These analyses did not give any data of particular significance. Earlier in the report, it was stated that the Na percentage in the exchange complex was not a major impairment in this soil. This statement was based on the excellent yields of barley and sorghum obtained after leveling and leaching. Replaceable Na was consistently higher in the 2 to 12-inch samples than in the 0 to 2-inch samples which represent a part of the penetration problem. It is highest in the soil from the D replicates and lowest in the A replicates. There is some evidence that replaceable Na was reduced in the 2 to 12-inch samples by sulfuric acid, gypsum, and sulfur. There was no evidence of replaceable Na reduction in the soil from the IBMA plots (Table 27).

Water soluble Na was highest in the C and D replicates, particularly in the 0 to 2-inch samples. Since all the plots received the same amount of irrigation water, it is evident that the slow intake of water in the C and D replicates contributed to the salt accumulation in these replicates. There is little or no difference in the relation between treatment and soluble Na, showing that leaching is the major factor in salinity control

Table 27. Replaceable Na and water soluble Na in soil samples taken after 1954 sorghum crop.

Treatment per acre	Replaceable Na (m.e./100 gms.) Replicates A	B	C	D	Water soluble Na (m.e./100 gms.) Replicates A	B	C	D	replaceable	water soluble
				0 to 2-inch samples						
IBMA, 1,000 lbs.	1.1	1.5	1.3	0.8	1.0	1.0	1.9	1.0	1.2	1.2
Sulf. acid, 110 gals.	1.0	0.9	1.4	0.6	0.8	0.4	1.1	2.6	1.0	1.2
Sulf. acid, 220 gals.	1.4	1.0	1.6	0.7	0.5	0.5	1.7	2.2	1.2	1.2
Gypsum, 1 ton	1.0	0.2	1.1	0.8	0.9	1.1	0.9	4.8	0.8	1.9
Gypsum, 5 tons	1.1	1.2	1.4	0.4	1.0	0.8	1.1	3.3	1.0	1.5
Sulfur, 1 ton	0.9	0.8	2.1	0.4	0.7	0.8	2.1	2.0	1.0	1.4
Manure, 10 tons	1.1	0.9	2.1	0.6	0.9	0.8	3.6	2.8	1.2	2.0
Manure, 20 tons	1.4	0.9	1.6	0.6	1.1	0.6	1.1	2.2	1.1	1.2
Manure, 10 tons; gypsum, 5 tons	0.9	1.0	1.6	0.4	0.6	0.6	1.1	3.2	1.0	1.4
Manure, 10 tons; sulfur, 1 ton	1.1	0.7	1.5	0.4	0.8	0.7	1.6	2.5	0.9	1.4
Cal. poly., 40 gals.	0.9	1.0	0.4	1.7	0.8	0.4	0.8	2.7	1.0	1.2
Cal. poly., 100 gals.	1.2	1.0	2.6	0.8	0.7	0.8	2.8	4.0	1.4	2.1
Soylaid, 400 lbs.	1.6	1.1	1.4	1.2	0.7	1.2	2.7	2.1	1.3	1.7
Soylaid, 1 ton	1.1	1.0	2.0	0.7	0.6	1.4	3.0	2.1	1.2	1.8
Orzan, 1 ton	1.3	0.9		0.7	1.2	0.4	4.3	2.7	1.0	2.1
PR-51, 40 lbs.	1.1	1.2	3.2	0.3	0.7	1.1	2.4	2.3	1.4	1.6
Check	1.3	0.9	1.5	0.7	0.9	2.0	1.7	3.9	1.1	2.1
Check	1.2	1.1	1.4	0.8	0.9	1.5	3.1	3.2	1.1	2.2
Average	1.1	1.0	1.9	0.7	0.8	0.9	2.1	2.7		

Table 27. (continued)

Treatment per acre	Replaceable Na (m.e./100 gms.)				Water soluble Na (m.e./100 gms.)				replaceable	water soluble
	Replicates				Replicates					
	A	B	C	D	A	B	C	D		
	2 to 12-inch samples									
IBMA, 1,000 lbs.	1.7	3.8	3.9	3.2	1.9	2.6	2.3	1.8	3.1	2.1
Sulf. acid, 110 gals.	1.5	2.1	2.8	5.1	1.7	0.8	1.6	1.9	2.9	1.5
Sulf. acid, 220 gals.	1.2	1.6	2.3	3.0	1.4	1.3	1.7	2.2	2.0	1.6
Gypsum, 1 ton	2.1	3.7	1.1	3.9	2.2	1.7	1.1	2.7	2.7	1.9
Gypsum, 5 tons	0.9	2.1	2.8	3.9	2.4	1.4	0.9	2.9	2.4	1.9
Sulfur, 1 ton	1.1	3.5	2.8	2.2	1.9	1.0	2.5	2.0	2.4	1.8
Manure, 10 tons	2.0	3.4	2.9	3.7	2.2	1.4	2.0	1.9	3.0	1.9
Manure, 20 tons	1.1	3.1	2.2	4.9	1.9	1.4	1.3	1.7	2.8	1.6
Manure, 10 tons; gypsum, 5 tons	1.9	2.7	2.5	4.4	2.4	0.7	1.7	2.1	2.9	1.7
Manure, 10 tons; sulfur, 1 ton	1.4	3.3	2.7	3.0	2.3	1.1	2.4	2.1	2.6	2.0
Cal. poly., 40 gals.	1.9	3.0	2.5	3.3	2.0	1.4	1.4	1.7	2.7	1.6
Cal. poly., 100 gals.	1.7	3.0	5.6	3.4	2.3	1.4	1.7	2.0	3.4	1.8
Soylaid, 400 lbs.	2.7	3.6	3.4	4.3	1.8	1.5	2.2	1.6	3.5	1.8
Soylaid, 1 ton	1.4	3.9	3.9	3.4	1.5	1.8	2.2	2.1	3.1	1.9
Orzan, 1 ton	1.4	3.9	3.5	3.1	2.2	0.8	2.7	2.0	3.0	1.9
PR-51, 40 lbs.	2.4	3.9	3.9	3.2	2.1	1.4	1.8	1.9	3.3	1.8
Check	2.1	1.4	3.6	4.1	2.4	2.5	1.9	2.4	2.8	2.3
Check	2.9	3.5	3.5	3.5	2.0	2.0	2.2	1.8	3.3	2.0
Average	1.7	3.1	3.1	3.6	2.0	1.5	1.9	2.0		

in this soil. The relative rate of capillary rise and infiltration rate and their influence on the accumulation of salt in the C and D plots is well illustrated by the data given in Table 27.

Replaceable potassium data are given in Table 28 for the 0 to 2-inch samples. The analyses of the 2 to 12-inch samples are omitted for brevity since they offered very little additional data of significance. The soil from the C and D replicates is considerably higher in replaceable K than the soil from the A and B replicates. The average of 18 samples from 18 plots, both 0 to 2 and 2 to 12-inch, in each replicated group of plots is as follows:

	m.e. k/100 grams	
Replicates	0-2 inches	2-12 inches
A	3.6	4.7
B	4.3	6.6
C	6.6	5.8
D	5.9	5.7

It may be of interest to repeat that surface soil was moved from A and B to C and D in leveling the land prior to starting the field experiment. Since the deposition of silt and clay on the surface of the soil and its subsequent crusting appears to be a major factor in the impaired penetration of water in this soil, and particularly in replicates C and D, this indicates that a high replaceable K percentage contributes to the water penetration problem in this soil. There is further evidence of this in the data obtained which show that there is a greater difference in replaceable K in the 0 to 2-inch samples than in the 2 to 12-inch samples for all four replicates where the water penetration problem is most severe. Additional evidence of this will be presented in later pages of this report where a brief study of the effect of replaceable K on water movement in soil will be presented. The data in Table 28 show some reduction in replaceable K in the 0 to 2-inch samples from the IBMA, sulfuric acid, gypsum, and sulfur treatments.

Salinity The conductivity of the saturation extract shows that the highest salinity is present in the C and D replicates and this correlates with the data on soluble Na in Table 28. The salinity data indicate that this may have had some effect on the yields obtained in the field experiment. It is also evidence that there was an impairment in water intake because of the character of the surface crust in the C and D replicates.

Calcium is a base that plays an important role in the chemical reactions which influence soil properties. The soluble calcium in the saturation extract was determined in order to examine the variation between plots and replicates. These data are given in Table 28 as m.e./liter of saturation extract. As mentioned in the discussion of the irrigation water used on this land, there was a favorable Ca percentage and undoubtedly this Ca content of the water contributed much to the soluble Ca found in the saturation extract of these soils. On the basis of many analyses of the irrigation

Table 28. Analysis of 0 to 2-inch soil crust samples after 1954 sorghum crop; cond. sat. ext., sol. Ca, rep. K.

Treatment per acre	Cond. sat. ext. (m.mhos/cm.) Replicates:				Sol. Ca in Sat. Ext. (m.e./liter) Replicates:				Replaceable K (m.e./100 gms.) Replicates:			
	A	B	C	D	A	B	C	D	A	B	C	D
IBMA, 1,000 lbs.	3.6	2.6	6.2	4.0	16	8	24	14	3.9	4.4	5.6	4.5
Sul. acid, 110 gals.	2.4	1.7	5.7	9.3	11	6	27	48	2.7	3.4	4.8	5.7
Sul. acid, 220 gals.	2.0	2.8	9.0	7.2	7	12	53	41	3.5	3.4	5.4	5.9
Gypsum, 1 ton	5.3	5.8	5.2	14.0	25	24	24	82	3.7	4.4	4.6	6.5
Gypsum, 5 tons	7.2	3.0	7.0	13.0	49	13	47	81	4.4	4.0	5.5	5.6
Sulfur, 1 ton	4.5	5.0	10.2	8.2	27	31	58	53	3.5	3.9	5.7	5.1
Manure, 10 tons	4.7	3.8	12.0	7.7	17	14	39	26	3.9	3.9	8.6	5.5
Manure, 20 tons	5.3	3.7	6.0	7.6	19	12	25	28	3.8	4.6	6.1	6.4
Manure, 10 tons; gypsum, 5 tons	2.8	4.3	7.0	13.0	10	24	45	70	3.5	4.3	6.1	6.5
Manure, 10 tons; sulfur, 1 ton	5.4	4.3	9.5	9.0	34	26	59	58	4.1	4.5	6.2	6.1
Cal. poly., 40 gals.	2.2	1.8	4.5	6.7	9	7	19	25	3.2	3.8	7.1	7.3
Cal. poly., 100 gals.	7.5	4.0	10.3	15.0	41	16	44	77	3.4	4.7	9.4	6.5
Soylaid, 400 lbs.	2.4	6.4	11.7	5.5	7	28	52	20	4.4	4.5	6.1	5.7
Soylaid, 1 ton	4.2	6.0	10.5	7.2	18	24	39	27	3.2	4.8	5.8	5.7
Orzan, 1 ton	5.0	2.2	14.0	10.0	18	8	56	42	3.2	4.4	8.4	5.3
PR-51, 40 lbs.	3.6	6.3	8.0	8.0	13	23	28	35	2.8	5.0	7.3	4.6
Check	4.0	9.0	6.4	10.5	15	44	20	42	3.7	3.7	6.4	7.4
Check	5.5	8.5	9.2	11.3	26	39	30	42	4.3	5.5	9.9	5.1
Average	4.3	4.5	7.9	9.3	20	20	38	45	3.6	4.3	6.6	5.9

water used in the field experiment, the quantity of calcium added per acre-foot of water varied between a minimum of 200 and a maximum of 600 pounds Ca. The data in Table 28 indicate that the Ca in the irrigation water was in most part responsible for the Ca differences between replicates as the values correlate with the differences in conductivity of the saturation extract.

Barley Crop - 1954-55

Following the 1954 sorghum crop, the experimental area was planted to barley on December 7, 1954, and was irrigated on December 11. In all the previous plantings in this project, no commercial fertilizer was used. One reason for this was that the soil analysis showed a good supply of available phosphate and the irrigation water being used contained some nitrate nitrogen. For the 1954-55 barley crop, 60 pounds of nitrogen per acre as ammonium nitrate were applied on November 26 and another 50 pounds on March 11, 1955.

The soil treatments for this experiment are the same as for the preceding sorghum crop and all were residual from the sorghum experiment except ferric sulfate which was applied on April 1, 1955, at the rate of 1,000 pounds per acre, to see if it would increase the rate of water penetration. Several cultural treatments were added to the experiment. One plot in each replicate was planted in rough-plowed land, one plot was mulched with coarse plant residue from the sorghum crop, and one with chopped residue. The two latter tests were included in order to examine the effect of mulch on surface crusting and seedling emergence.

Infiltration rate The rate of water penetration in each plot was measured at each of seven irrigations during the growth of this crop. In the sorghum experiment, the volume of standing water in the plots was estimated 24 hours after the application of irrigation water.

In this barley planting, the determinations were made by placing a graduated stake in each plot and measuring the drop in standing water level. These data are given in Table 29 as mm. per hour.

The first irrigation on December 11 is given separately for each plot and for each replicate in order to show the difference in replicates and treatments. The six irrigations made subsequently are given as the average for all six. The reason for this breakdown is that the first irrigation on this land is always most rapid. At this point the land is broken and the surface film of silt and clay is absent. The penetration problem is most in evidence as the layer of silt and clay is deposited by subsequent irrigations.

For the December 11 irrigation, the infiltration rates in replicates C and D are just about half of those in A and B. The effect of the treatments, the average of the four replicates on December 11, is clearly evident in column 6 of Table 29. IBMA, sulfuric acid, gypsum, and the coarse mulch treatments all show a favorable effect on infiltration rate. It is also of interest that the manure applications have manifested some improvement at this point.

Table 29. Infiltration rates, mm. per hour,* for December 11 irrigation and average 6 irrigations. Barley experiment, 1954-55.

Treatments per acre	December 11 irrigations Replicates A	B	C	D	Av. 4 rep. Dec. 11 irrigation	Av. 6 irrigations
1. 1 ton sulfur	13	11	8	6	9.5	6.0
2. ½ ton iron sulf. (applied Apr.1)						7.7
3. 100 gals. cal. poly.	10	8	5	7	7.5	5.1
4. 10 tons manure	12	20	--	8	13.3	6.5
5. 20 tons manure	15	18	9	6	12.0	7.0
6. 1 ton gypsum	7	12	13	6	9.5	7.0
7. 5 tons gypsum	12	12	16	6	11.5	8.2
8. Manure, 10 tons; gypsum, 5 tons	22	16	7	9	13.5	8.3
9. Manure, 10 tons; sulfur, 1 ton	12	14	7	9	10.5	6.4
10. IBMA	19	26	8	10	15.7	11.7
11. Straw mulch	18	17	9	6	12.5	8.3
12. 110 gals. sulfuric acid	19	16	7	7	12.2	8.7
13. 220 gals. sulfuric acid	24	19	7	6	14.0	10.6
14. Chopped mulch	13	7	7	8	8.7	5.7
15. Soylaid	16	8	5	5	8.5	5.9
16. Orzan	10	15	6	8	9.8	---
17. Rough tillage	14	9	5	5	8.2	4.7
18. Check	11	8	6	7	8.0	5.2

*Readings calculated from 2-hour readings taken immediately after application of water.

The average rate of water penetration for the six subsequent irrigations, shown in column 7, Table 29, indicates a favorable residual effect for IBMA, sulfuric acid, and gypsum. The manure treatment did not maintain the apparent improvement mentioned above after the deposit of silt and clay formed on the surface of the soil. Iron sulfate applied April 1 at the rate of 1,000 pounds per acre, did not show any appreciable effect on infiltration when applied at this period, in the growth of the crop and the settled state of the soil.

Rough tillage did not have any effect on infiltration rate, and the reason for this is evident in Plates 18 and 19. The soil disperses and crusts just as quickly from rough tillage as from regular tillage, and seedling emergence was only in the surface cracks.

<u>Emergence</u> On February 1, seedling emergence counts were made on quadrats (8 square feet) in each of the 72 plots. These data are given in Table 30, calculated to 1,000 plants per acre. Each treatment in each of the four replicates is given separately because of the soil variation in the field and the variation between replicates. In the seventh column of the table, the average for the C and D replicates is given separately because of the poor growth in these. As in the sorghum planting, emergence was least in the D replicates. For the different treatments, the greatest emergence was obtained in the plots treated with IBMA and 5 tons of gypsum. The mulching treatments showed some improvement over the checks. Rough tillage showed greater emergence than the checks in the A and C replicates but less in the B and D replicates.

<u>Vegetative growth</u> On April 28, height-of-plant measurements were made in each of the 72 plots in order to get an estimate of the comparative vegetative growth by treatments and replicates. These data are given in Table 31. In agreement with the emergence data, the IBMA and gypsum treatments were making the best growth at this date. The growth in the C and D replicates was less than in the A and B replicates.

<u>Yield of grain</u> The grain yields in pounds per acre are given in Table 32. By replicates, the yields are in the order, most to least, A, B, C, and D. On the basis of the average of each treatment in the four replicates, the yield increase from IBMA, 5 tons gypsum, manure plus gypsum, and 220 gallons sulfuric acid per acre are significant at 1 percent, and the 100 gallons sulfuric acid at 5 percent. Rough tillage had no effect, nor did calcium polysulfide show any improvement. Plate No. 21 shows the excellent stand of barley obtained and the reclamation of the land.

Cotton and Alfalfa Planted in 1955

<u>Cotton</u> In 1955, the west half of the Gilbert experimental area was used for a cotton fertilizer test and plant tissue analysis study, and incidentally, to learn how effective the reclamation had been. Dates of planting for the cotton were April 1, May 1, and June 9, to study the effect of date of planting on tissue analysis and on the yield of cotton lint. The yields of cotton lint obtained from this experiment were as follows:

Planting Date	Lint per Acre
April 1	952 lbs.
May 1	1,135 lbs.
June 9	1,486 lbs.

Table 30. Seedling emergence counts, 1,000 plants per acre; by treatments and replicates on February 1.

Treatments per acre	Replicates A	B	C	D	Av. Rep. A,B,C,D	Av. Rep. C,D
1. 1 ton sulfur	450	276	267	229	305	248
2. ½ ton iron sulfate (4/1)	276	363	294	169	275	231
3. 100 gals. cal. poly.	384	211	229	180	251	204
4. 10 tons manure	464	319	163	240	294	201
5. 20 tons manure	377	464	490	163	373	326
6. 1 ton gypsum	261	305	365	142	268	253
7. 5 tons gypsum	326	407	617	218	392	417
8. 10 tons manure; 5 tons gypsum	617	290	360	202	367	281
9. 10 tons manure; 1 ton sulfur	370	334	169	267	285	218
10. IBMA	623	384	714	622	586	668
11. Coarse mulch	450	334	533	202	379	367
12. 110 gals. sulf. acid	537	276	321	202	334	261
13. 220 gals. sulf. acid	442	276	305	240	316	272
14. Soylaid	428	422	387	321	390	354
15. Chopped mulch	334	399	223	408	341	315
16. Rough plow	174	268	212	256	228	234
17. Check	239	160	250	180	207	215

Table 31. Height of plants on April 28; barley experiment, 1954-55.

Treatment per acre	Replicates A in.	B in.	C in.	D in.	Average in.
1. 1 ton sulfur	37	36	31	33	34
2. ½ ton iron sulfate (4/1)	37.5	32	31.5	29	32
3. 100 gals. cal. poly.	33	37	31	33.5	33
4. 10 tons manure	40.5	36	31.5	32.5	35
5. 20 tons manure	41	33	40.5	30	36
6. 1 ton gypsum	40	38.5	35	33	37
7. 5 tons gypsum	37	34.5	36	36	37
8. Manure, 10 tons; gypsum, 5 tons	36	38	33	37	36
9. Manure, 10 tons; sulfur, 1 ton	39	35	29	31.5	34
10. IBMA	40	36	38.5	43.5	39
11. Coarse mulch	37	33	35	34.5	35
12. 110 gals. sulf. acid	41	36	34	31	35
13. 220 gals. sulf. acid	34.5	35.5	35.5	35	35
14. Chopped mulch	33	38	34	34.5	35
15. 1 ton soylaid	36.5	36	31	30.5	34
16. Rough tillage	39	37	36	31	36
17. Check	39	33	32	35.5	35
Average	37.7	35.8	33.8	33.5	

Table 32. Yield of grain per acre;
Barley experiment 1954-55.

Treatment per acre	Replicates A	B	C	D	Average
	pounds				
IBMA	4429	3464	4631	5061	4392**
5 tons gypsum	4240	3640	4035	3936	3963**
Manure, 10 tons; gypsum, 5 tons	4350	4426	4005	2849	3907**
220 gals. sulf. acid	3959	3762	3545	3914	3795**
110 gals. sulf. acid	4081	4268	3004	2950	3576*
Soylaid	3596	4124	2908	2982	3402
1 ton gypsum	4011	3874	3804	1854	3386
Manure, 10 tons; sulfur, 1 ton	4411	3663	2178	3105	3339
20 tons manure	4050	3363	4166	1684	3316
Check	4422	2805	2590	2500	3079
Rough plow	4312	4064	3056	1745	3294
10 tons manure	4651	3420	2796	2268	3284
Coarse mulch	4809	3029	3422	1833	3273
Chopped mulch	4041	3623	2672	1873	3052
1 ton sulfur	4143	4149	2120	1632	3011
***100 gals. cal. poly.	3031	3592	1887	2067	2644
Average	4158	3704	3175	2640	

***Eliminated from comparison **Significant at 1% *Significant at 5%

This cotton experiment showed that the land had been effectively reclaimed. The average of the three dates of planting was in excess of 2 bales per acre. It is evident from this test that the high replaceable K percentage in this soil does not restrict growth of cotton despite the adverse effect on the structure of the soil. The test further indicates that salinity is the major growth-limiting factor to contend with in this soil.

Alfalfa After the barley crop had been harvested on the east half of the 16-acre Gilbert experimental area, alfalfa was planted preparatory to turning the land back to the owner. As shown in Plate 21, all of this area was left fallow during growth of the barley crop, 1954-55, except the two borders used for the replicated experiment. When the area was planted to alfalfa in November, 1955, the germination and emergence of alfalfa were poor in the area that had been fallowed, but good in the two borders that had been cropped to barley. The poor stand of alfalfa in the fallowed area was more or less expected on the basis of the soil studies showing proportionately active capillary rise and restricted infiltration in this soil. This capillary rise-infiltration relation is typical for this soil and is the cause of a salt accumulation in the surface soil sufficient in one year to reduce germination of alfalfa seed. In other words, it is necessary to apply a heavy pre-plant irrigation before planting a crop on this land, or in any other similar combination of soil characters.

SUPPLEMENTARY INVESTIGATIONS

In a reclamation experiment in which the effect of soil conditioners on soil structure is being studied, it is essential that certain other studies be conducted to aid in the interpretation of field data. During the reclamation of the Gilbert area, studies were conducted in the laboratory on the conditioner value of orzan, polysulfides, pyrite, pyrrhotite, copiapite, and on the influence of a high potassium percentage in the exchange complex on soil properties.

Orzan

In the field experiments conducted with orzan, this material failed to show any promise as a soil conditioner either in the growth of the crop or in soil behavior. Orzan is completely soluble in water and, obviously, its effect on the soil will depend upon whether the soil has a capacity to fix this sulfonated lignin compound. The first laboratory experiment was with orzan L-45 solution, using soils from the Gilbert reclamation experiment and the Safford Experiment Farm.

Five hundred gram portions of soil were weighed into each of 10 glazed clay pots of 1 liter capacity. These were leached with the solutions given in Table 33. Three hundred and forty ml. of water per 500 grams of soil is closely equivalent to 1 acre-foot of water per acre-foot of soil. When the first 340 ml. of water had drained below the surface, an additional 340 ml. were added. After the drainage of this was complete, the soils were allowed to dry in the pots and then ground to break up the lumps. The soil was returned to the pots and leached with another 2-acre feet of water. The samples were again leached with 2 acre-feet of water after the second drying period, making a total of 5 acre-feet equivalent of water after orzan and the gypsum had been applied.

Table 33. Description of treatments with orzan and gypsum, and effect on capillary rise for Gilbert and Safford soil.

Treatment per 500 grams soil	Capillary rise, cm., 24 hours Gilbert soil	Safford soil
1. Tap water	9.4	6.0
2. Tap water plus 1 ml. orzan L-45*	9.1	6.5
3. Tap water plus 5 ml. orzan L-45*	8.9	7.0
4. Tap water plus 10 ml. orzan L-45*	5.0	7.0
5. Tap water plus 20 ml. orzan L-45*	6.0	11.0
6. Tap water saturated with gypsum*	25.0	22.1
7. Tap water saturated with gypsum plus 1 ml. orzan L-45*	24.0	23.0
8. Tap water saturated with gypsum plus 5 ml. orzan L-45*	23.1	18.7
9. Tap water saturated with gypsum plus 10 ml. orzan L-45*	17.5	25.4
10. Tap water saturated with gypsum plus 20 ml. orzan L-45*	19.0	24.0

*Materials applied in first leaching only.

The rate at which the orzan solution and the succeeding applications of water drained through the soil varied somewhat. Both soils showed little or no fixation of orzan as shown by the dark color of the drainage water. For the first acre-foot of water, the infiltration rate for the treated soils, in comparison with the controls, was reduced by orzan in the Gilbert soil but was increased in the Safford soil to which 5, 10 and 20 ml. or orzan solution were added. All of these are heavy applications when calculated to a per-acre basis. The gypsum increased the drainage rate in both soils.

The drainage water from each successive two-acre feet equivalent irrigations was combined and analysed for conductivity, Na, and K. Soil samples were removed from each pot after each 2 acre-feet of water had drained through the soil and these were analysed for exchange capacity, exchangeable Na and K, and capillary rise.

This large amount of analytical data is omitted for brevity. Suffice it to say that the analyses of both leachates and soils, at the three sampling periods, showed a progressive reduction in replaceable Na and K for the soils to which the gypsum had been applied alone and in combination with orzan. The results obtained from the capillary rise test are given in Table 33 for the soils after leaching with the conditioner solutions and five additional acre-free equivalent of water. For both soils, the orzan had little or no effect on capillary rise of water in the soil column but both soils showed improvement from gypsum.

Incubation test Because of the solubility of orzan and its loss from the soil in the drainage when the soil is irrigated soon after application, another experiment was conducted in which the soils were incubated for 60 days after mixing with dry orzan "A". The moisture content of the soil was maintained at 60 percent of the water-holding capacity during the incubation period. The dry orzan "A" was mixed with the soils at the rate of 1, 2, 10, and 20 tons per acre-foot of soil. At the end of the 60 days' incubation period, the soils were dried and ground to pass a 2mm. sieve and tested for modulus of rupture, infiltration rate, and capillary rise. These data are given in Table 34 for three soils, namely, the Gilbert soil, the Safford soil, and a black alkali soil from the land of the Greene Cattle Company in the southern part of the State.

Attention is called to the fact that these soils were tested without preliminary leaching; that is, the orzan was present in the soils when the tests were made. The data in Table 34 show that orzan had little or no effect on capillary rise of water except when added in excess of 2 tons per acre-foot of soil. At the rates of 10 and 25 tons per acre, capillary rise was definitely increased. Infiltration rate was increased by heavy applications of orzan in the Safford soil to a greater extent than in the Gilbert soil. There was no drainage from any except the 20-ton application to the black alkali soil. All the drainage from the soils treated with orzan "A" was dark, showing that it was not fixed or precipitated during incubation for a period of 60 days. This experiment suggests that orzan may be more suited to non-irrigated land.

The modulus of rupture data are somewhat inconsistent in that the Gilbert soil was affected differently than the other two soils. For the Safford soil, the modulus of rupture was significantly reduced by orzan, and the reduction is stepwise with increase in quantity of orzan applied to the soil. This is in agreement with the effect of orzan on infiltration rate in this soil. For the two other soils, the modulus of rupture was increased by orzan with one exception, namely, the heaviest application to the black alkali soil.

Because of the appearance of color in the water extracts of all the soils incubated for 60 days, another experiment was conducted to obtain information on the decomposition of this material, using evolution of carbon dioxide as an indicator. The method proposed by Heck (10) was used and the carbon dioxide measured by absorption in an alkaline solution. The evolution of carbon dioxide was determined for the intervals 0 to 3, 3 to 6, 6 to 9, and 9 to 12 weeks. The data obtained are given in Table 35.

This incubation test shows that there is some oxidation of orzan in these two soils, but it is not significant.

Field Test In the 1954-55 barley field experiment, the orzan plots were used to examine the effect of this material on the soil rather than on the growth of the crop. A quadrat was measured off in the center of each orzan plot in each replicate, and this quadrat divided into quarters as follows: (a) untreated soil, check; (b) 1,000 pounds orzan per acre; (c) 2,000 pounds orzan per acre; and (d) 1,000 pounds orzan and 1 ton gypsum per acre. These materials were applied on December 29, 1954 and were well mixed with the surface six inches of soil. Ninety days were then allowed for incubation and for any chemical or physical reactions with the soil. At the end of this ninety-day period, samples of soil were taken from each of the plots in each of the four replicates. The analyses of these are given in Table 36. After the soil samples had been taken, the plots were spaded, so that the soil would take water better, and were then irrigated on April 1, 1955 and on April 30, 1955. Plates 22, 23, and 24 show the condition of the soil before irrigation, after it had been allowed to incubate for ninety days and then spaded; after the irrigation on April 1; and after a second irrigation on April 30.

The analyses of the soil samples for capillary rise, infiltration rate, and modulus of rupture (Table 36) do not show any effect from incorporation of orzan and a ninety-day period of incubation. For the gypsum treatment, there was an increase in capillary rise and infiltration rate and a decrease in modulus of rupture. For all the samples from the orzan treatments, the water extracts had considerable color and the depth of color was in proportion to the amount of orzan mixed with the soil. This was interpreted as showing that the orzan had not been fixed or appreciably decomposed during incubation. There was less color in the water extract of the soil treated with 1 ton gypsum and 1,000 pounds orzan than in the soils treated with orzan alone, and this indicates that soluble calcium will precipitate orzan to a limited extent. Aldrich and Martin (1) found a small initial aggregating effect on the soil from orzan (ammonium lignin sulfonate) upon incubation. Our studies indicate that there is a small initial effect from heavy applications but this effect disappears when the soil is subjected to continuous irrigation.

Table 34. Effect of 60 days incubation of three soils with orzan; capillary rise, infiltration rate, and modulus of rupture.

Treatment per acre	Capillary rise (cm. 24 hrs.)	Infiltration rise (ml. 24 hrs.)	Mod. of Rupt. (mil. bars)	Color of leachate
		Gilbert soil		
1. Control	23.0	122	2599	none
2. 1 ton orzan	23.0	91	3875	yellow
3. 2 tons orzan	23.0	113	5072	yellow
4. 10 tons orzan	24.0	139	3449	dark
5. 20 tons orzan	24.0	232	3686	very dark
		Safford Soil		
1. Control	10.1	202	3544	none
2. 1 ton orzan	10.1	216	2993	yellow
3. 2 tons orzan	12.0	406	2520	yellow
4. 10 tons orzan	16.1	648	1701	dark
5. 20 tons orzan	20.0	2160	110	very dark
		Greene Soil		
1. Control	2.9	0	4454	
2. 1 ton orzan	2.9	0	5213	
3. 2 tons orzan	3.6	0	4977	
4. 10 tons orzan	4.1	0	4599	
5. 20 tons orzan	6.0	12	1229	very dark

Table 35. Carbon dioxide evolution from Gilbert and Safford soils; mgms. CO_2 from 100 gms. soil mixed with orzan.

Mgms. orzan per 100 gms. soil	Incubation in weeks 3	6	9	12	Total
	Mgms. CO_2,		Gilbert		Soil
0	102	56	56	35	249
25	116	86	68	43	313
50	124	135	65	41	365
250	173	88	70	44	375
	Mgms. CO_2,		Safford		Soil
0	176	103	73	44	396
25	195	114	69	50	428
50	212	124	72	50	458
250	178	145	70	50	443

Table 36. Capillary rise, infiltration rate, and modulus of rupture for soils from field experiment with orzan.

Treatment	Replicate	Capillary rise (cm. 24 hrs.)	Infiltration rate (ml. 24 hrs.)	Modulus of Rupture (millibars)
Check	A	22.1	130	2962
	B	38.0	300	1806
	C	11.0	24	2537
	D	16.6	115	2758
Average		21.8	142	2516
1,000 lbs. orzan	A	21.1	134	3560
	B	40.0	320	2001
	C	12.0	36	2772
	D	11.8	70	2913
Average		21.1	140	2811
2,000 lbs. orzan	A	21.6	144	3024
	B	39.2	330	1686
	C	12.0	29	2852
	D	16.6	86	3229
Average		22.3	147	2693
1,000 lbs. orzan plus 1 ton gypsum	A	36.0	320	2503
	B	48.5	870	1512
	C	15.1	84	2427
	D	19.0	132	2314
Average		29.6	350	2189

Experiments with Polysulfides

The supporting laboratory studies on calcium, ammonium, potassium, and sodium polysulfides have been reported elsewhere (14).

Briefly, these studies showed that all four of these polysulfides oxidize readily in the soil, and that calcium sulfate is one of the products of this oxidation. When they are added to the soil in quantities to supply sulfur equivalent to the gypsum requirement of the soil, the calcium ammonium, and potassium polysulfides produced an improvement in soil structure as measured by capillary rise and infiltration rate of water; however, when applied at the rate of 20 to 50 gallons per acre in the irrigation water, there was no evidence of improvement in water movement in the soil.

Experiments with Pyrite, Pyrrhotite, and Copiapite

These three materials were not used in the field experiments reported here; however, since they have been mentioned as having some value as soil conditioners, some rather extensive laboratory experiments were conducted with them. These studies are reported elsewhere (15).

Pyrite does not oxidize with sufficient rapidity in the soil to have any soil conditioning value.

Pyrrhotite, an unstable iron sulfide, oxidizes quite rapidly in the soil. The rate of oxidation is closely equal to that of sulfur. Its value as a soil conditioner will depend upon the supply available and whether it can be supplied at a reasonable cost.

Copiapite, which is a hydrated iron sulfate mineral and an oxidation product of pyrite in nature, is equivalent to commercial iron sulfate in soil conditioning value.

Replaceable Potassium Studies

Review of literature A review of literature on the replaceable bases in alkali soils shows that a high replaceable potassium percentage in the exchange complex often occurs, particularly in black alkali soils. There is not, however, a great deal of information available on the role, if any, that a high replaceable K percentage plays in the behavior of these soils. DeSigmond (5) quotes Gans as having observed, as early as 1905, that colloidal Na, K, and NH_4 zeolites are mucous, sticky materials difficult to filter. Kelley (12) mentions an observation made by Hissink in 1907 as follows: "After leaching separate samples of soil with several salt solutions for a few days, the soils were then leached with distilled water. Within less than one day, the soils previously leached with NaCl and KCl became impervious to water." Studies at the U.S. Regional Salinity Laboratory (6) have shown that the saturation of montmorillonite clays and soils with K, followed by drying, decreases the inter-layer swelling. Reeve et al (18) conducted a study of the effect of replaceable Na and K on air and water permeability and modulus of rupture. Replaceable K had little effect on the stability of soil structure as measured by air-water permeability ratio. There was a decrease in water permeability, with increase in replaceable Na and K. The magnitude of the change and the rate at which the decrease takes place are much greater for the Na-treated soils than for the K-treated soils. The modulus of rupture tests showed that replaceable K had essentially no effect on this property for five soils; and for three soils, it decreased significantly with increasing replaceable K. Aldrich and Martin (1) found that on varying the percent exchangeable K from 2 to 60, there was a marked reduction in aggregates. In this soil, K had a dispersing effect similar to Na; however, the K soil crumbled easily when dry, wet easily, and was not slick when wet. The Na soil was exceedingly difficult to crumble, wet with difficulty, and was slick when wet. This description of the soil with high K percentage in the exchange complex is in agreement with the properties noted for the Gilbert soil with a high K percentage. Quirk and Schofield (17) have recently studied this problem by determining the permeability of KCl and NaCl solutions of varying concentration. The curves obtained by plotting percent decrease in permeability against time for the two salts were similar, but the decrease occurred at lower concentration for the KCl solutions. There was definite evidence of clay deflocculation when the soil was leached with a $1X10^{-2}$ molar KCl solution.

Examination of two soils with varying Na and K percentages   The effect of exchangeable Na and K in the soil varies, particularly with respect to dispersion. An equal degree of Na and K saturation in soils of similar texture have shown wide differences in permeability. Soils dispersed by high Na and K percentages are soils of low density which settle slowly to form large settling volumes of gelatinous consistency and tend to close the pores and restrict water movement. Calcium clay settles rapidly to a smaller settling volume.

In irrigated agriculture, the movement of water in the soil is an important factor in growth of crops and, of course, this is influenced by the aggregation of the soil particles. Irrigation farmers are more interested in the rate at which the soil "takes" water than the way it plows.

Throughout this investigation, capillary rise and infiltration rates were used to examine the effect of soil conditioners on soil structure, largely because water movement in soils is foremost in the minds of irrigation farmers. The tests are simple and can be made on a large number of samples at one time. The value of these tests and their application to the study of disturbed soil samples, as influenced by Na and K percentage, is illustrated in Figures 5, 6, 7, and the modulus of rupture in Figure 8. Figure 5 shows the relation between Na percentage in the exchange complex and infiltration rate and capillary rise for a soil in which the Na percentage varied from a minimum of 10 percent to a maximum of 26 percent. In Figures 6 and 7, the relation between Na and K percentage and infiltration rate and capillary rise is shown for two soils. Figure 8 shows the relation between Na and K percentage and modulus of rupture.

These charts illustrate how the tests may be used and their effectiveness in evaluating the effects of Na and K percentage on soil structure and the improvement resulting from replacement of Na and K by Ca. The tests are particularly useful where the experiment involves a comparison of the effect of several different soil conditioners on a single soil, such as in this reclamation experiment.

It is of particular interest to note that the effect of potassium percentage in the exchange complex on capillary rise, infiltration rate, and modulus of rupture is similar to that of sodium but of lesser magnitude.

Preparation of soils with high Ca, Mg, Na and K percentages To study further the effect of high K percentage in the exchange complex, two soils were selected for laboratory studies on the effect of high percentages of Ca, Mg, K and Na. One-kilogram portions of soil were mixed with concentrated solutions of $CaCl_2$, $MgCl_2$, KCl, and NaCl, filtered on a large Buchner funnel, washed with solutions of the respective salts, and then with distilled water to remove the excess of soluble salt. The soils were then dried in the air and ground to pass a 2mm. sieve. An examination of the soils for capillary rise was made using the method of Gardner (9). The rate of rise was determined as cm. rise for a 24-hour period. The infiltration rate was determined by the method already described (6) except that the results were expressed as ml. for a 24-hour period. The infiltration test was made on a column of soil 5.5cm. in length and 5.2cm. in diameter which was first wet by capillarity and then placed under constant head of 7.5cm. tap water. The soils were also analysed for replacement capacity and replaceable Na, K, and Mg. The data are given in Table 37. The soils used were from the Gilbert experimental plots and the Safford Experiment Farm.

The analyses for replaceable bases show that replacement, or percent saturation, with the respective bases was not complete, but, from the tests presented, it is evident that the percentage saturation was sufficient to give the specific cation effects. Following are the analyses of the soils showing percent saturation accomplished.

	Gilbert Soil	Safford Soil
Percent replaceable Ca in high Ca soil	53	80
Percent replaceable Mg in high Mg soil	50	62
Percent replaceable K in high K soil	71	55
Percent replaceable Na in high Na soil	46	48

Capillary rise tests were made on the soils with both tap water and tap water saturated with gypsum. The data obtained are shown in Table 37 and Figure 9. For both soils, there is a stepwise reduction in rate of capillary rise, most to least, for Na, K, Mg as compared to the high Ca soil. The rate of capillary rise for the Gilbert soil with a 72 percent K saturation is only slightly higher than the same soil with 48 percent Na saturation. The results obtained with the Safford soil with 55 percent K saturation show a lesser reduction in capillary rise than the Gilbert soil at 72 percent K saturation. The Na percentage in the two soils is practically the same but with the higher clay percentage and exchange capacity in the Safford soil, there is greater reduction in capillary rise.

In the tests with gypsum-saturated water, there is some improvement in capillary rise in all cases as compared to tap water alone, but the improvement is greater for the soil with a high K percentage than for the soil with high Na percentage.

Infiltration rate was determined with tap water and tap water saturated with gypsum, and the rates were recorded for the 0 to 24 and 24 to 48-hour periods. These data are given in Table 37 and Figure 10. For the Gilbert soil, the rate was higher for the soil with high Mg percentage than for the soil with high Ca percentage, as was also the improvement when gypsum-saturated water was used. The infiltration rate was greatly reduced in

Table 37. Effect of high Ca, Mg, K and Na percentage on capillary rise, infiltration rate, and modulus of rupture.

	Cap.Rise cm.24hrs.	Infiltration Rate 24hrs.	24-48hrs.	Mod.Rupt. mil.bars	Exch.Cap. m. e.	Exch.Mg per 100 grams	Exch.Na per 100 grams	Exch.K per 100 grams
Gilbert soil								
High Ca percentage	46.6	518	470	1922	13.5	2.9	0.4	3.0
High Mg percentage	39.4	610	619	----	16.0	8.0	0.5	2.5
with gypsum-saturated water	39.8	739	948					
High K percentage	16.0	46	41	2252	14.0	2.2	0.5	10.0
with gypsum-saturated water	31.0	350	281					
High Na percentage	12.0	26	5	3277	14.5	2.7	6.7	2.0
with gypsum-saturated water	15.6	67	62					
Safford soil								
High Ca percentage	37.4	439	439	1812	28.0	3.0	0.6	2.0
High Mg percentage	29.5	250	134		25.5	15.8	2.2	7.4
with gypsum-saturated water	35.0	408	329	----				
High K percentage	20.9	130	110	2427	27.5	3.4	1.0	15.1
with gypsum-saturated water	37.4	379	221					
High Na percentage	1.0	0	0	----	27.5	3.2	13.1	1.5
with gypsum-saturated water	2.9	0	0					

both the soils with high K and Na percentages and the difference between the two is small. The improved rate obtained with gypsum-saturated water is significantly greater for the soil with the high K percentage than for the soil with the high Na percentage.

For the Safford soil, the major difference in the infiltration rate is for the soil with high Mg percentage; that is, there is a reduction in infiltration rate but an improvement where gypsum-saturated water was used. The soil with a high Na percentage was completely "frozen" and there was no improvement from gypsum-saturated water for the 48-hour period. High K percentage greatly reduced infiltration rate in this soil.

The leachates from the high K percentage soils were colored from dissolved organic matter showing that the potassium-clay hydrolizes in the same manner as the sodium-clay.

Modulus of rupture tests were made on the soils with the high Ca, Mg, K and Na percentage and these values are given in Table 37. For both soils, the values are in the order, low to high, Ca, K, and Na. It was not possible to wet the briquette prepared from the Safford soil with high Na percentage; but, from other tests made with this soil, the effect of high Na on the modulus of rupture has been shown to increase with increasing Na percentage.

Settling volume The volume occupied by a given weight of soil from a water suspension is often used to illustrate dispersion and aggregation. The settling volume of these soils was determined by shaking 30 grams of air-dry soil with water in a 50ml. graduated cylinder. The volumes obtained, after standing one week, were as follows:

	Settling Volume ml.	
	Gilbert	Safford
High Ca percentage	26	33
High Mg percentage	26	33
High K percentage	27	35
High Na percentage	28	48

The volume of the Gilbert soil was only slightly increased by high Na and K percentages in the soil. Initially, that is after standing 24 hours, the settling volume for the high Na and K soils was greater than after one week, largely because of the clay layer on the surface. This clay layer was drawn into the pores to a certain extent on standing for a week and thus reduced the difference in final settling volume between the four soils. This is typical of the condition observed in the field and its effect on intake of water. The high K percentage in the Safford soil gave a slight increase in volume, while the increase from high Na percentage was of considerable volume. In both soils with high Ca and Mg percentages, settling was rapid with a clear water above the soil. There was no surface layer of clay. The soils with the high K and Na percentages settled slowly and remained cloudy for a prolonged period. Final readings were made at the end of one week and at this time the deposit of clay on the surface of the Gilbert soil was 1.5 and 3.0ml. for the high K and Na soils, and 5.0 and 5.5ml. for the Safford soil.

The crusting character of the Gilbert soil and the effect of gypsum on this are illustrated by a plating experiment shown in Plate no. 23. The numbers 1, 2, and 3 represent the Gilbert soil leached with ammonium acetate and then saturated with Ca, desalinized soil with no other treatment, and soil after leaching with saturated gypsum solution. The desalinized soil shows the worst state of crusting and cracking, and the soil treated with gypsum shows some improvement. Replaceable K was determined in these three soils. The original replaceable K was 4.7m.e./100 grams. This was reduced in number 1 to 0.5m.e./100 grams, and in number 3 to 2.8m.e./100 grams.

Relation between capillary rise and infiltration rate During the course of our laboratory experiments with this Gilbert soil, the relation between the rate at which water rose by capillarity in a soil column and the rate of infiltration varied somewhat from the normal relation exhibited by other Arizona soils. This difference was manifested by a rapid rate of capillary rise and slow infiltration rate. There is evidence that the high K percentage in the exchange complex and the surface film of silt and clay deposited from each irrigation contributes to the low infiltration rate. For example, in replicates C and D of the field experiment, salinity was more difficult to reduce than was true for replicates A and B. Water penetration was slower in the replicates C and D, and this correlates with a higher K percentage in the exchange complex for the surface, 0 to 2-inch, crust of the soil in the C and D replicates than in the A and B replicates. The ease with which water rises by capillarity in the C and D replicates and the slowness with which water penetrates represent a combination of factors which impairs desalinization.

The following experiment supports this statement. In Figure 11, the capillary rise and infiltration rates for the two soils with high Ca and K percentages are given, in comparison with the same soils as they came from the field and before conversion to high replaceable Ca and K percentages. The difference in the relation between capillary rise and infiltration rate for the Gilbert and Safford soils is clearly evident in the figure, both for the field samples and the soils after conversion to a high K percentage. Furthermore, when the field sample and the high K percentage Gilbert soil are compared with the same soil containing a high Ca percentage, the evidence is more convincing that the high K percentage in the Gilbert soil contributes to the inherent problem, namely, crusting, cracking and salinization.

Adsorbing Area of Gilbert Soil

The high replaceable K percentage and the "melting" and settling of the soil fractions when the soil is irrigated suggested an examination of the adsorbing surface in the Gilbert soil. The presence of mixed layer minerals in the soil imparts certain swelling and ion exchange properties, and the respective capacities for swelling and ion exchange vary with the type of clay mineral that is dominant in the soil.

Dyal and Hendricks (7) have proposed an ethylene glycol retention method for determining the total and external adsorbing areas of clay, and from these, the internal adsorbing surface can be calculated by difference. From these and similar data on the adsorbing areas of the common clay minerals, the adsorbing areas for clay minerals in the soil can be estimated. The adsorbing surfaces were determined for the Gilbert

Table 38. Total, external, and internal adsorbing area of Gilbert soil, compared with other Arizona soils; m^2/gm.

Soil, or mineral	Adsorbing Area: Total	External	Internal	External/Internal
Illite	120	111	9	12.3
Arizona bentonite	176	48	128	0.37
Montmorillonite	520	83	437	0.19
Montmorillonite	540	56	484	0.12
Mingus soil	229	82	137	0.60
Safford soil	160	55	105	0.52
Avondale soil	50	21	29	0.72
Yuma Valley soil	62	27	35	0.77
C.G. Farm soil	132	41	91	0.45
Roll Valley soil	103	30	73	0.41
Roll Valley soil	105	30	75	0.40
Experimental Farm, Mesa	78	24	54	0.44
Campbell Av. Farm soil	11	6	3	0.20
Gilbert soil	69	33	36	0.92

soil and a number of other Arizona soils and clay minerals using a modification of the Dyal and Hendricks method proposed by Bower and Gschwend (3). The data obtained are given in Table 38.

The ratio between the external and internal adsorbing surface varies between 0.2 and 92m^2/gm. This may be compared with an external to internal ratio of 12.3 for a sample of illite and 0.23 for three samples of mortmorillonite. Buehrer, Robinson, and Deming (4) have shown these two minerals to be dominant clay minerals in Arizona soils. The data in Table 38 indicate that this soil is predominantly montmorillonitic but contains a higher percentage of illite than the other soils as indicated by the ratio of external to internal adsorbing surface.

The external adsorbing surface of most soils lies in the range of 10 to 50m^2/gm. and the internal adsorbing surface between nil in soils that contain no interlayer swelling minerals to as high as 150m^2/gm. in soils with a high content of expanding lattice-type minerals (montmorillonite). All the soils listed in Table 38 fall within these ranges.

In Figures 12, 13 and 14, the total internal and external adsorbing surfaces for a number of Arizona soils are plotted against clay (.005mm.) percentage and exchange capacity. In each of these charts, the Gilbert soil is marked with an "X". The relationships are essentially linear and the Gilbert soil does not vary greatly from the linear relation.

Montmorillonite and Kaolinite do not contain appreciable potassium and differ from illite in this respect. According to Russell (19), if the soil-forming processes lead to the formation of illite-type minerals, there is a mechanism for holding potassium in the soil against leaching. The total potassium was determined in a sample of Gilbert soil and was found to be 2.72 percent or 69.7m.e./100 grams. In this same sample, the replaceable potassium was 4.6m.e./100 grams; thus, even though the replaceable K in this soil is high, it represents only a small fraction of the total potassium in the soil percentagewise.

DISCUSSION

This investigation was concerned with the reclamation of a soil containing a moderately high Na percentage, a high K percentage in the exchange complex, and a high salinity. It involved a study of leveling and leaching, field and laboratory tests with a number of soil conditioners, and research on the effect of high K percentage in the exchange complex on soil properties.

The field experiment was located on a 16-acre tract of land located $6\frac{1}{2}$ miles south of Gilbert, Arizona. This land was leased to the Arizona Agricultural Experiment Station for a period of 5 years. At the time it was leased, it had been abandoned because of salinity and alkalinity.

A preliminary examination of the soil showed a high salinity, high potassium and magnesium percentage in the exchange complex, a moderately high sodium percentage, a very low organic matter content, and silt and clay fractions that were highly dispersed when wet. The surface of the soil crusts on drying and cracks badly, yet it breaks up easily to a single grain structure. The soil behaved as though it were entirely devoid of binding agents.

A study of the composition of the irrigation water used on the land and well waters in the immediate vicinity of the area did not supply information that might explain the condition of the soil, particularly the high potassium percentage, the moderately high sodium percentage, and the high salinity. The quality of the water was good to fair, and should not have caused either the high salinity, high potassium percentage, or marginal sodium percentage. In other words, the water was not directly responsible for this being a problem soil.

The soil analysis and the analyses of the irrigation water samples indicated that leaching out the salt with water of this quality should restore the inherent fertility of this land.

Proceeding on this basis, the land was leveled and divided into 18 borders. It was then leached to remove the excess salt. A soil conditioner experiment was then installed involving a comparison of sulfur, gypsum, calcium polysulfide, polyelectrolyte HPAN, and PR-51. Except for a few localized spots, the barley crop planted on the area made excellent growth, particularly in the untreated check borders. There was some response in yield for HPAN and gypsum and a laboratory examination of soil samples taken from the area showed improvement in rate of water movement in the soil to which these two conditioners had been applied. The grain yields varied between a minimum of 2,760 and a maximum of 3,722 pounds per acre, which is quite good for unfertilized barley.

Following the barley crop, sorghum was planted and the grain yields from this test were also good. The yields varied somewhat because of bird damage from a minimum of 1,816 to a high of 3,689 pounds grain per acre. The best yield was from the HPAN treatment. The other treatments were not significantly different from the checks.

Up to this point, the progress of the reclamation phase of this project indicated that leveling and leaching will reclaim this land and restore its productive capacity. This conclusion is based on the soil analysis and the growth of barley and sorghum in the check plots where no soil conditioners were applied.

Preceding the application of soil conditioners in 1952, a set of soil samples was taken for future reference. After the sorghum crop had been harvested in 1953, another set of soil samples was taken and both sets analysed at this time. These analyses showed a reduction in sodium percentage in all plots. This confirmed the opinion expressed after the first soil analysis and the analysis of the irrigation water. It showed that the water was not directly the cause of the problem that had developed and that, in so far as salinity and sodium percentage are concerned, these can be removed as contributing factors by leveling and leaching. In order to obtain more fundamental information on the effect of soil conditioners on this type of soil, it was necessary to reduce the size and increase the number of plots for replication and randomization of treatments. To accomplish this, two of the borders were divided into 36 plots each. This was a sufficient number for 16 different treatments replicated 4 times, as well as 8 check plots. The soil conditioners used in this experiment were sulfuric acid, sulfur, gypsum, calcium polysulfide, manure, soylaid, orzan "A", PR-51, and the polyelectrolyte IBMA. Sorghum was planted as the test crop.

During the course of this experiment, data on water penetration, seedling emergence, and yield of grain were obtained in the field, and a number of soil samples were analysed in the laboratory. IBMA, sulfuric acid, and gypsum were most effective in increasing water penetration and seedling emergence. The soil tests showed a highly significant decrease in modulus of rupture and an increase in aggregation for the soil from the IBMA plots, as well as a significant decrease in modulus of rupture, for the soil from the sulfuric acid plots.

During the course of this study, an important observation was one in which the water movement by capillary rise was rapid in proportion to the infiltration rate. The soil solution which contains dissolved salts rises by capillarity and deposits salts on the surface by evaporation, and the extent of accumulation depends upon the rate of capillary rise and rate of infiltration. The capillary rise data did not indicate impaired structure but the infiltration rate did. It was observed in the field that the infiltration rate decreased markedly with each successive irrigation. The reason for this progressive decrease in infiltration rate is that the silt and clay fractions are highly dispersed when wet, because of lack of binding agents, and at each irrigation there is a build-up of this dispersed soil fraction in, and on, the surface soil. This film causes the surface to crust and crack when dry. There is evidence that the high potassium percentage in the exchange complex contributes to this.

The yield of grain in this experiment did not show any significant differences. The yields were good in all plots, varying between a low of 2,948 pounds and a high of 3,951 pounds grain per acre. This adds further support to the statement made previously that leveling and leaching will restore the productive capacity of this soil.

After harvesting the sorghum crop, soil samples were taken from each of the 72 plots. These were analysed in comparison with soil samples taken before application of conditioners and just preceding the planting of the sorghum. Laboratory tests on the second set of samples showed an improvement in capillary rise, infiltration rate, and modulus of rupture for the soils from the plots treated with IBMA, sulfuric acid, gypsum, and sulfur. The manure application of 20 tons per acre reduced modulus of rupture.

The sorghum crop was followed by winter barley. The soil treatments for this crop were residual from the sorghum planting except that rough tillage and mulched plots were added. Rate of irrigation water penetration and plant emergence were determined in the field, and the results obtained were in close agreement with the rate and count for the sorghum crop. IBMA, sulfuric acid, gypsum, and coarse mulch plots showed the most rapid infiltration rate. Rough tillage had no favorable effect because the soil "melted" just as rapidly from rough tillage as from regular tillage. The greatest seedling emergence was in the IBMA and gypsum plots. A measurement of vegetative growth (height of plants) was made in early Spring and these showed best growth in the IBMA and gypsum plots. The barley grain yields were significantly increased in the plots treated with IBMA, gypsum, sulfuric acid, and manure-plus-gypsum. None of the other treatments showed any significant improvement in yield. Commercial fertilizer was applied to all plots for this barley crop.

The thoroughness with which this land was reclaimed, although there is still some trouble from surface crusting, is illustrated by Plates 20 and 21. Plate 20 shows the growth of sorghum July, 1954 and Plate 21 shows the condition of the 1954-55 barley crop on May 3, 1955. In 1955, the west half of this 16-acre area was used for a cotton tissue analysis experiment. The reclaimed land produced in excess of 2 bales lint per acre.

This five-year study of the problem in this soil showed that the polyelectrolytes HPAN and IBMA, gypsum, sulfuric acid, and sulfur were definitely more effective in improving soil structure and plant growth than any of the other soil conditioning materials that were used. Calcium polysulfide, orzan "A", soylaid, and PR-51 failed to show any promise of conditioning value. The influence of the polyelectrolytes on water movement and growth of sorghum and barley was outstanding. These compounds have a pronounced influence on soil structure and the influence persists over a prolonged period of time. The first application of HPAN in 1952 showed a favorable residual influence in all the succeeding crops (see Plate 16). Soils of poor structure usually have a high bulk density, low permeability, and tendency to cake and crack on drying. According to Michaels and Lambe (16) the polyelectrolytes reduce bulk density, increase water retentive capacity, and increase permeability of air and water. At the present cost, the use of polyelectrolytes is not feasible on a farm scale. The favorable effect of synthetic polyelectrolytes on Arizona soils has been previously shown (8).

This investigation shows that the soil conditioners that have been in use for so many years, namely, gypsum, sulfur, and sulfuric acid, are the most economical and the most effective. In soils where there is a tendency for the clay to be dispersed, an occasional small application of gypsum or sulfuric acid in the irrigation water should be highly beneficial.

In addition to the field experiment, and supplemental to it, laboratory studies were conducted on the soil conditioning value of orzan, pyrites, and the polysulfides. The effect of high potassium percentage in the exchange complex on soil properties was also studied.

Orzan is an ammonium lignin sulfonate and a by-product of the paper pulp industry. It has been recommended as a soil conditioner because it has found use as a briquette and core-binding agent. It is completely soluble in water, and this property should obvisouly affect its value on irrigated soils unless it is precipitated or fixed by absorption in the soil.

The field tests with this material did not show any significant effect, either on growth or on soil properties. The soil was irrigated soon after the orzan was applied and the question arose as to whether the orzan had been leached out of the soil and whether an incubation period prior to irrigation and planting would be advisable. Laboratory and field incubation tests were conducted to study this.

Measurement of carbon dioxide evolution during incubation showed only very limited decomposition or oxidation. The water extracts of the incubated soil-orzan mixtures were very dark. This was evidence that little or no fixation or absorption of orzan had taken place in the soil. Capillary rise test showed no improvement in water movement in the soil from incubation with orzan; however, when the tests were made on the incubated soils from which the orzan was not removed by leaching, there was definite improvement in both capillary rise and infiltration rate of water when the orzan was mixed with the soil at the rate of 2 to 10 tons per acre-foot of soil or higher.

The laboratory experiments with orzan indicate that when soils are subjected to continuous irrigation, as they are in the Southwest, orzan is of doubtful value as a binding agent, but in non-irrigated soils, where much of the orzan will remain in the root zone, it should be useful.

Polysulfides The polysulfides failed to show any significant improvement in growth or soil properties in the Gilbert field experiment. Laboratory experiments were, therefore, conducted to gain additional information on the properties of these materials (14).

Incubation studies showed that the calcium, ammonium, potassium and sodium polysulfides all oxidize quite readily in the soil and that calcium sulfate is a product of this oxidation. It was also found that the polysulfides are carried deep into the soil by irrigation water and, thus oxidizable sulfur can be placed deeper in this form.

When added to the soil in quantities equivalent to the gypsum requirement of the soil, there is an improvement in soil structure and a reduction in replaceable sodium. However, when added to the irrigation water at the rates of 20 to 50 gallons per acre, which is the recommended application by those who propose this material as a soil conditioner, there is no evidence of improvement in movement of water in the soil.

Pyrites Laboratory studies were conducted with pyrite and the related minerals, pyrrhotite and copiapite. These studies, which are reported elsewhere (15), showed that pyrite oxidizes too slowly to be an effective soil conditioner. Pyrrhotite and copiapite are much more active chemically and have some value as soil conditioners.

Potassium percentage in the exchange complex One of the main reasons for selecting the Gilbert soil for soil conditioner research was the high potassium percentage in the exchange complex.

For the laboratory study of high potassium percentage, portions of two soils were treated with solutions of $CaCl_2$, $MgCl_2$, KCl, and NaCl in order to prepare soils with high saturation percentages of these four bases. After desalinization, drying, and grinding, the soils were tested for rate of capillary rise, infiltration rate, modulus of rupture, and settling volume. The capillary rise and infiltration rates were significantly reduced and the modulus of rupture increased by the high potassium percentage as compared to the soil with the high calcium percentage. The determination of the settling volume of these soils was particularly revealing. When the calcium and magnesium percentages were high, the soil settled rapidly and in its entirety. Where the potassium and sodium percentages were high, the larger soil particles settled quickly and the subsequent settling of the silt and clay formed a surface layer of some magnitude. This typifies the performance of the soil in the Gilbert experimental plots where the surface build-up of high-potassium-percentage clay dried to a crust that reduces seedling emergence and water penetration.

The laboratory experiments definitely showed that high potassium percentage in the exchange complex imparts unfavorable properties to this soil. Analyses of the 0 to 2-inch crust field samples showed a higher potassium percentage in the samples from the plots where penetration was slowest and where the conductivity of the saturation extract was highest. In other words, data from the laboratory tests with soils of high exchangeable potassium percentage correlate with the performance records taken in the field.

Salt accumulation Another phase of the investigation concerned the reason for the accumulation of salt and the moderately high sodium percentage which could not be attributed directly to the saline content and chemical composition of the irrigation water used on this land. One explanation for this is found in the data on capillary rise and infiltration rate. This soil possesses a peculiar property in which the movement of water by upward capillarity is very great in comparison with the infiltration rate. This is caused in part by the high potassium percentage and the build-up of the surface film and crust of silt and clay. Since the capillary movement of water upward and, therefore, movement of salt, is greater than the downward movement in the soil profile, this produces a concentration of salt in the surface soil.

Adsorbing surface The total, external, and internal adsorbing areas were determined for the Gilbert soil and also for a number of other Arizona soils for comparison. These data showed a near 1-to-1 ratio between the internal and external adsorbing area for the Gilbert soil.

There was a highly significant relationship between clay percentage, exchange capacity, and adsorbing areas for the group of soils examined.

CONCLUSIONS

Important among the results obtained from this investigation are:

1. The analyses of the soil and irrigation water available for use on the land are essential in planning a reclamation program.

2. Leveling the land to reduce slope and eliminate high and low spots in the fields where salts tend to accumulate, is of major importance.

3. Gypsum, sulfuric acid, and sulfur are dominantly superior soil conditioners as compared to the other conditioners used in these experiments.

4. A laboratory and field study of orzan, ammonium lignin sulfonate, indicates that this material may be better suited to non-irrigated lands than to irrigated lands.

5. Polysulfides are only useful conditioning agents when applied in quantities equivalent to the gypsum requirement of the soil.

6. Polysulfides are leachable and, therefore, will penetrate and carry oxidizable sulfur deep into the soil profile.

7. Waste pyrite, which is available in large quantities in the West, has little or no soil conditioning value.

8. Pyrrhotite and copiapite have conditioning value somewhat equivalent to iron sulfate.

9. The improvement in plant growth and soil structure for the Gilbert soil from HPAN and IBMA polyelectrolytes was outstanding, but these are rated below gypsum and sulfuric acid on the basis of cost.

10. The improvement in soil structure from HPAN and IBMA was confined largely to the surface 0 to 2 inches of soil as shown by the tests on samples taken at 0 to 2, and 2 to 12 inches.

11. The growth response to HPAN and IBMA, and the laboratory tests of effect on structure which showed that the major effect was on the 0 to 2-inch sample, emphasizes the important influence of the surface crust on the growth of the crop.

12. An inherent character of this soil which causes dispersion, surface crusting, and surface cracking is the high potassium percentage in the exchange complex.

13. The high exchangeable potassium percentage reduced capillary rise and infiltration rate and increased the modulus of rupture.

14. The effect of high potassium percentage on soil structure is similar to that of sodium except of lesser magnitude. Potassium causes a greater structural impairment when the soil is wet than when it is dry.

15. With respect to the growth of crops, the high potassium percentage does not exhibit the toxicity that is characteristic of a high sodium percentage.

16. An apparent effect of high potassium percentage in this type of soil is a high dispersion when wet and easy crumbling when dry.

17. None of the soil conditioners proved to be very effective in the reduction of replaceable potassium.

18. For the soils examined, the high potassium percentage showed a proportionately greater reduction in infiltration rate than capillary rise. This tends to increase the salinity of the surface soil.

19. After a period of fallow, this type of soil should be given a heavy preplant irrigation.

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The authors are indebted to W. A. Ryan, owner of the land, for a 5-year lease on 16 acres without charge; to D. C. Aepli for advice and help in getting the field experiment started; to the Chandler and Mesa S.C.S. work units; to J. R. Carter, assistant county agricultural agent, Maricopa county; to Miss Catherine Gairaud, who undertook the laboratory aggregate of rupture analysis; to W. H. Fuller for assistance in an advisory capacity; to Monsanto Chemical Company for fund and material support; and to the manufacturers and dealers who suppled the poly-electrolytes, PR-51, polysulfide, sulfuric acid, orzan, and soylaid.

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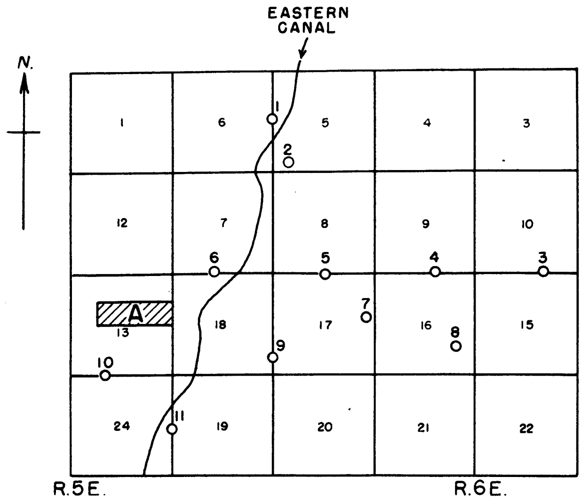


EAST HALF					WEST HALF
1 ton GYPSUM per acre					15 gals.CAL. POLY. per acre
5 tons GYPSUM per acre					40 gals. CAL. POLY. per acre
CHECK					1 ton SULFUR per acre
15 gals. CAL. POLY. per acre					CHECK
40 gals. CAL. POLY. per acre					5 tons GYPSUM per acre
ROUGH TILLAGE					1 ton GYPSUM per acre
CHECK	HPAN	CHECK	PR-51	CHECK	ROUGH TILLAGE
CHECK					CHECK
1 ton SULFUR per acre					ROUGH TILLAGE

→ SLOPE

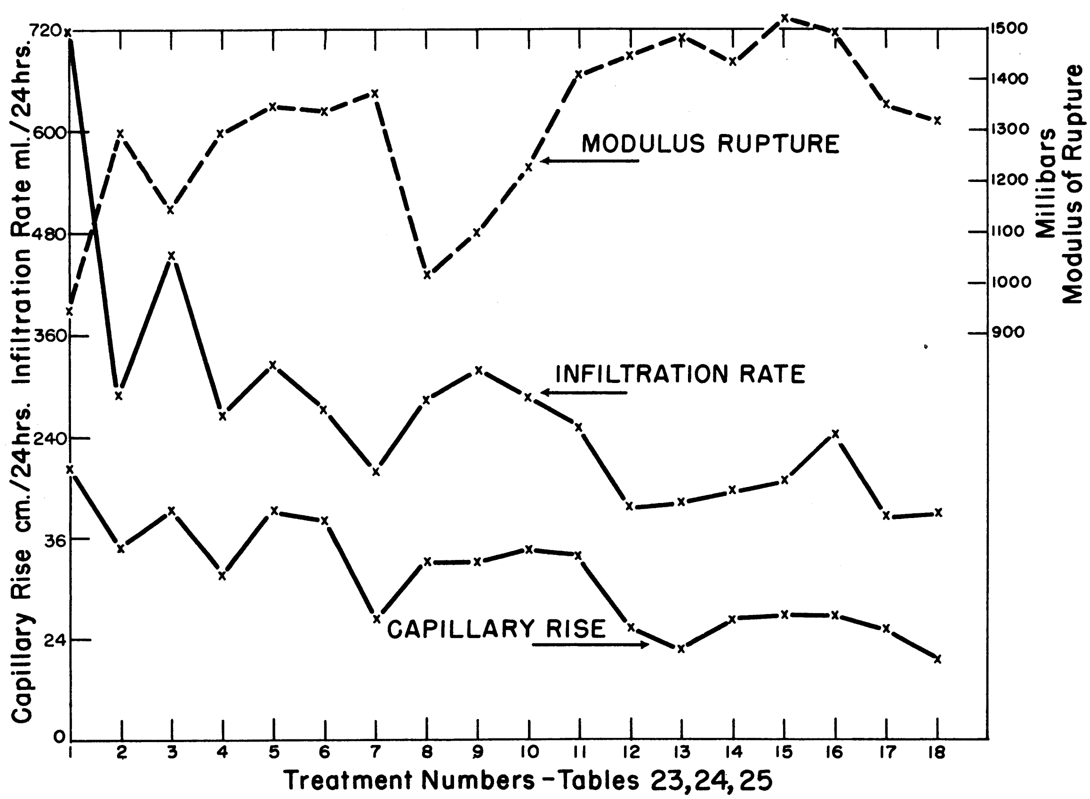
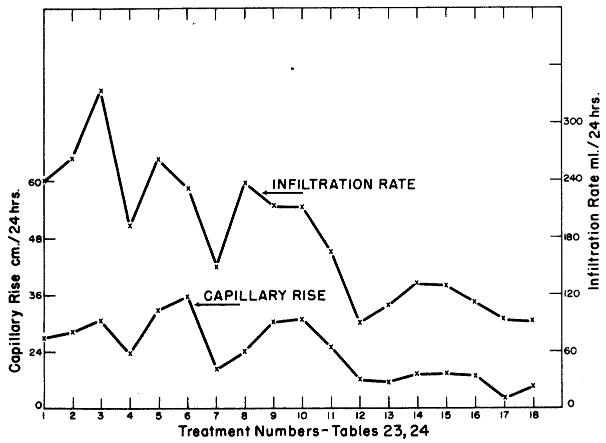
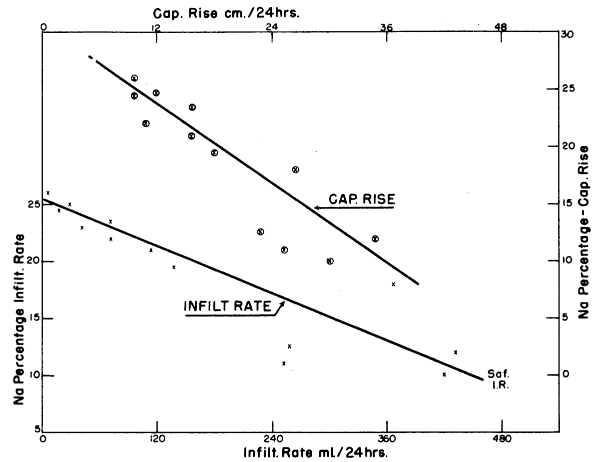


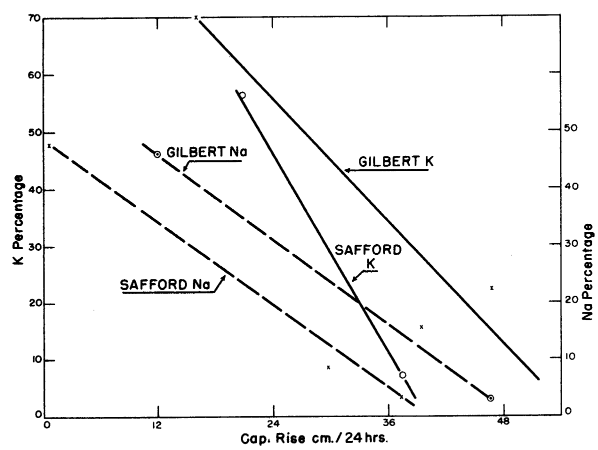
Figure 1. (Upper left) Location of wells and Eastern canal in relation to the experimental area. Wells are numbered as in Table 2 and "A" represents the experimental area. Each square represents a section of land.

Figure 2. (Upper right) Field plan for soil conditioner experiment - 1952.

Figure 3. (Lower) Comparison of rate of capillary rise, infiltration rate, and modulus of rupture for 0 to 2 inch soil sample from experimental plots.







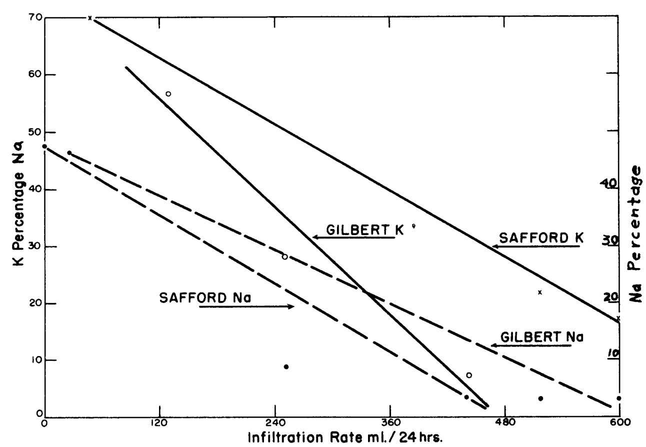
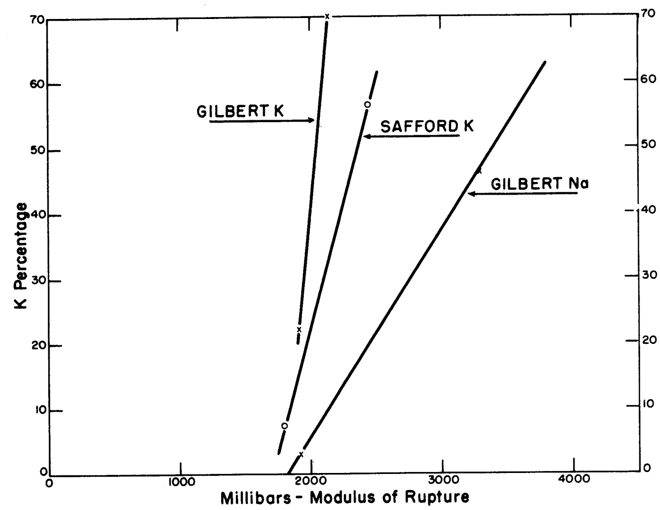


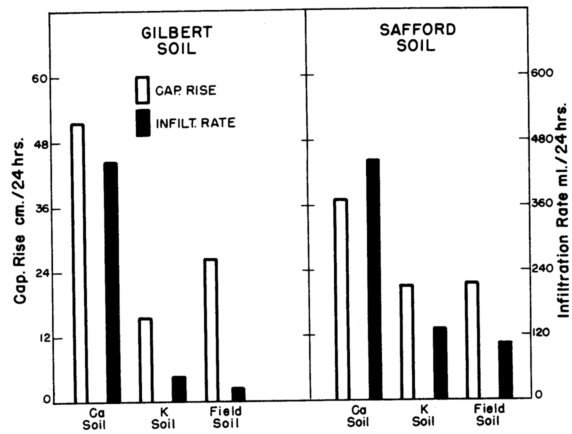
Figure 4. (Upper left) Comparison of rate of capillary rise and infiltration rate for 2 to 12 inch soil samples from experimental plots.

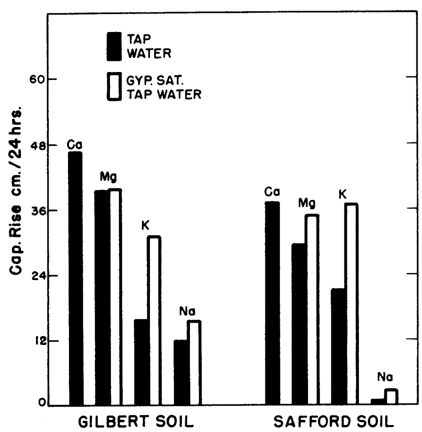
Figure 5. (Upper right) Relation between Na percentage in the exchange complex, capillary rise, and infiltration rate, Safford soil.

Figure 6. (Lower left) Relation between Na and K percentage in the exchange complex and capillary rise for Gilbert and Safford soils.

Figure 7. (Lower right) Relation between Na and K percentage in the exchange complex and infiltration rate. Gilbert and Safford soils.







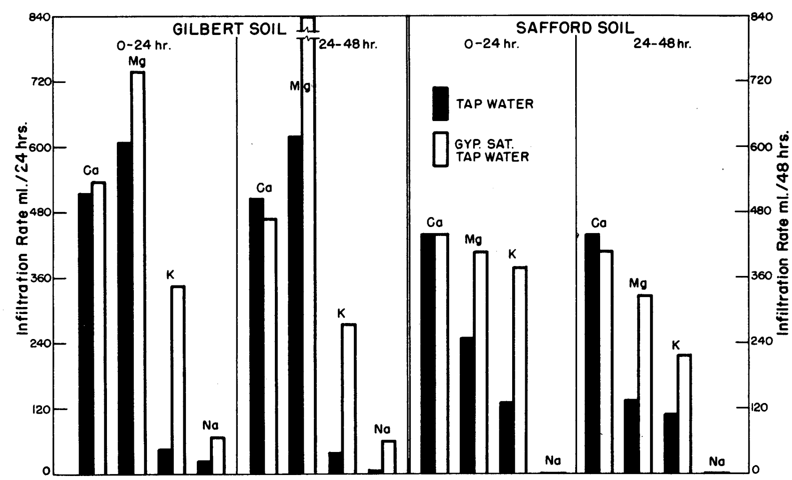
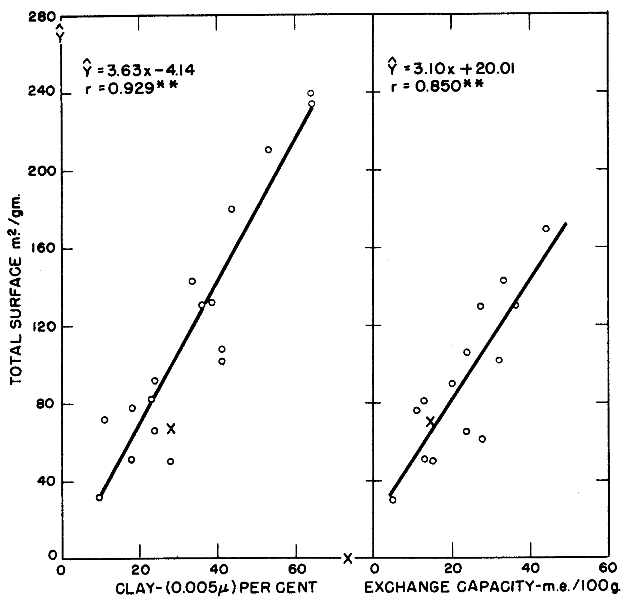


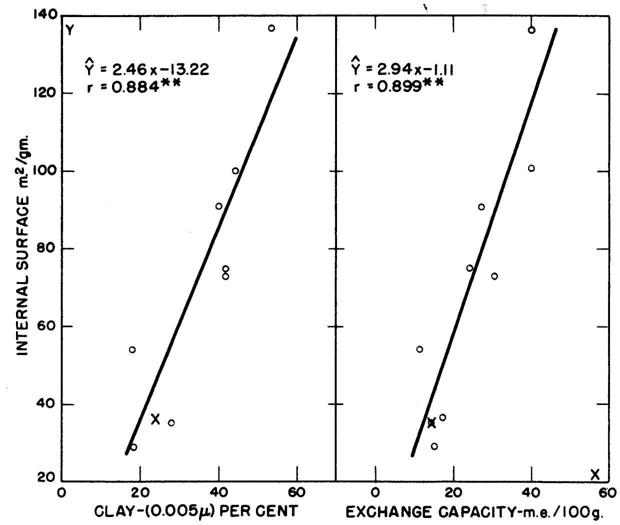
Figure 8. (Upper left) Relation between Na and K percentage in the exchange complex and modulus of rupture. Gilbert and Safford soils.

Figure 9. (Lower left) Comparative rate of capillary rise for Gilbert and Safford soils with high Ca, Mg, K, and Na percentages in the exchange complex.

Figure 10. (Lower right) Comparative rate of infiltration for Safford and Gilbert Soils. 0 to 24 and 24 to 48 hour periods with high Ca, Mg, K, and Na percentages in the exchange complex.

Figure 11. (Upper right) Relation between rate of capillary rise and infiltration rate for soils with high percentage of K in the exchange complex.





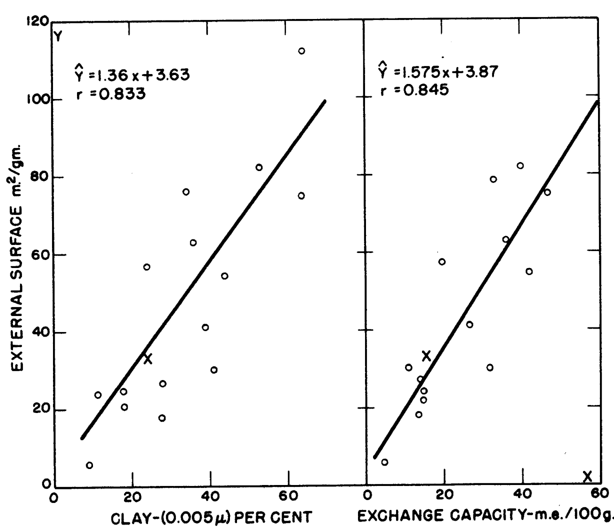


Figure 12. (Upper left) Relation between clay percentage, exchange capacity, and total adsorbing surface.

Figure 13. (Upper right) Relation between clay percentage, exchange capacity, and internal adsorbing surface.

Figure 14. (Lower left) Relation between clay percentage, exchange capacity, and external adsorbing surface.

Plate 1. Experimental area before reclamation

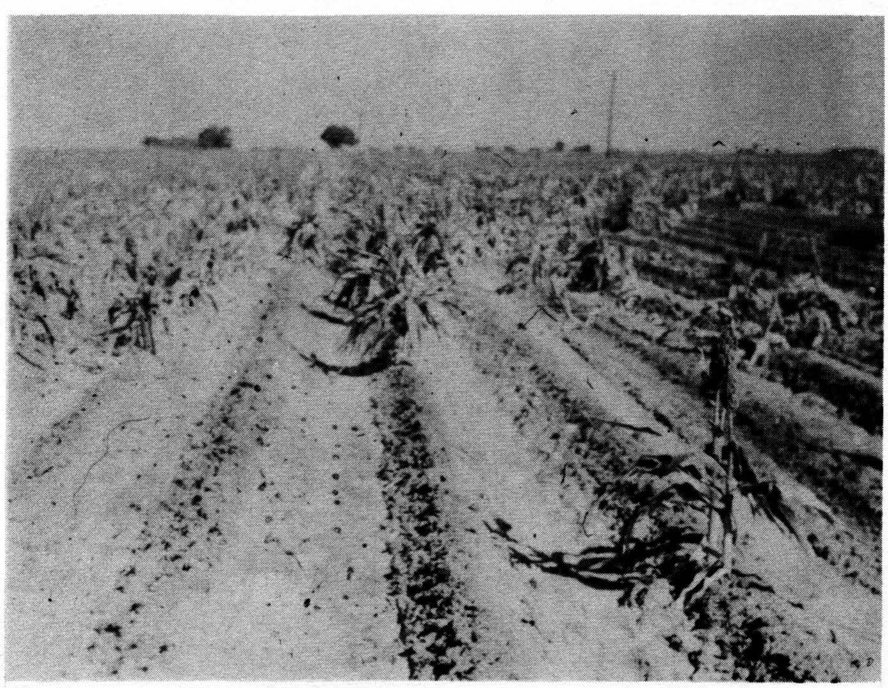


Plate 2. Growth of sorghum in neighboring field

Plate 3. Oat field south of experimental area; salinity too high for growth in foreground.

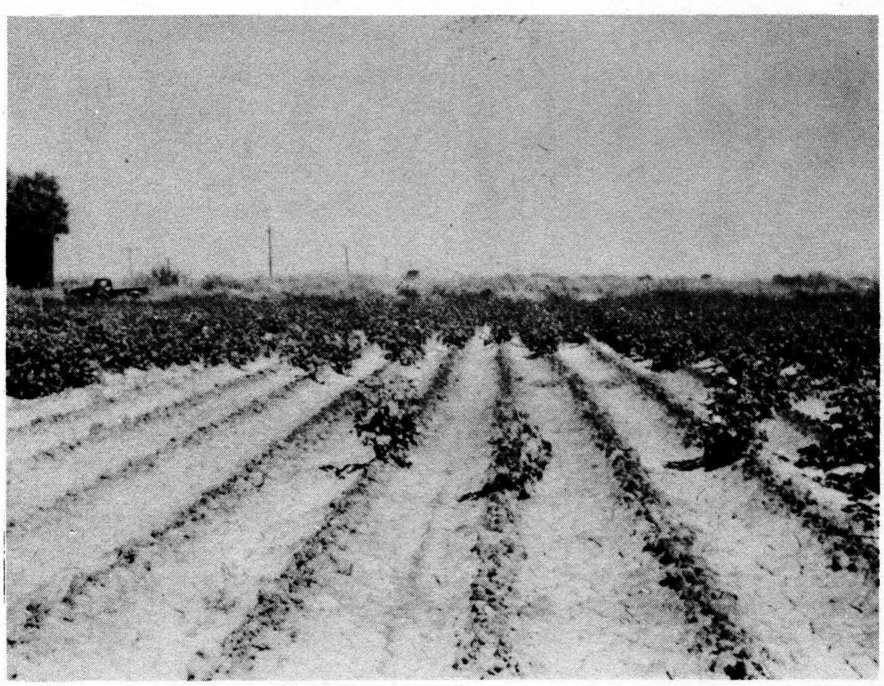


Plate 4. Growth of cotton in field east of experimental area.

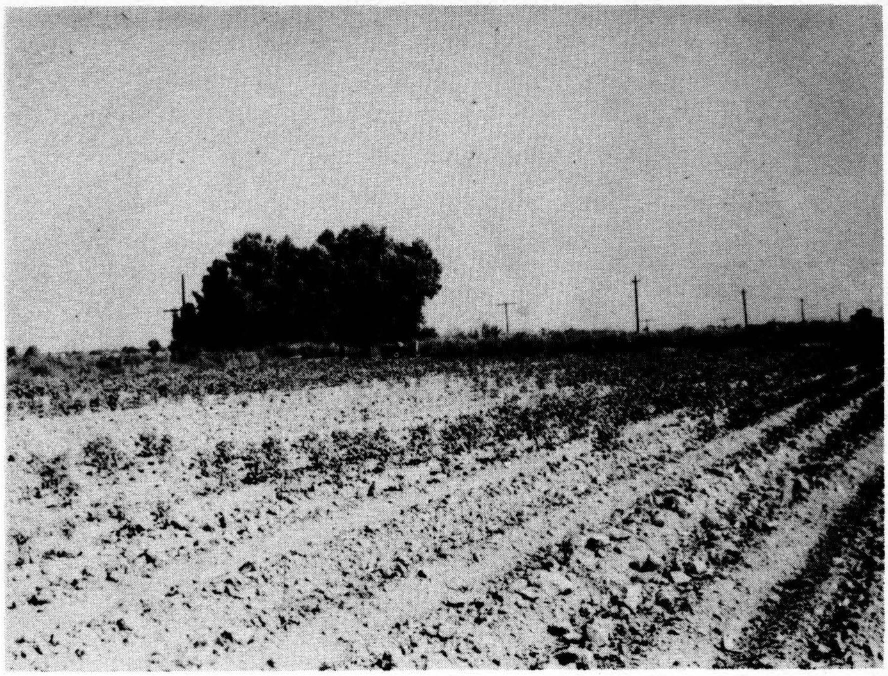


Plate 5. Growth of cotton in field southeast of experimental area.

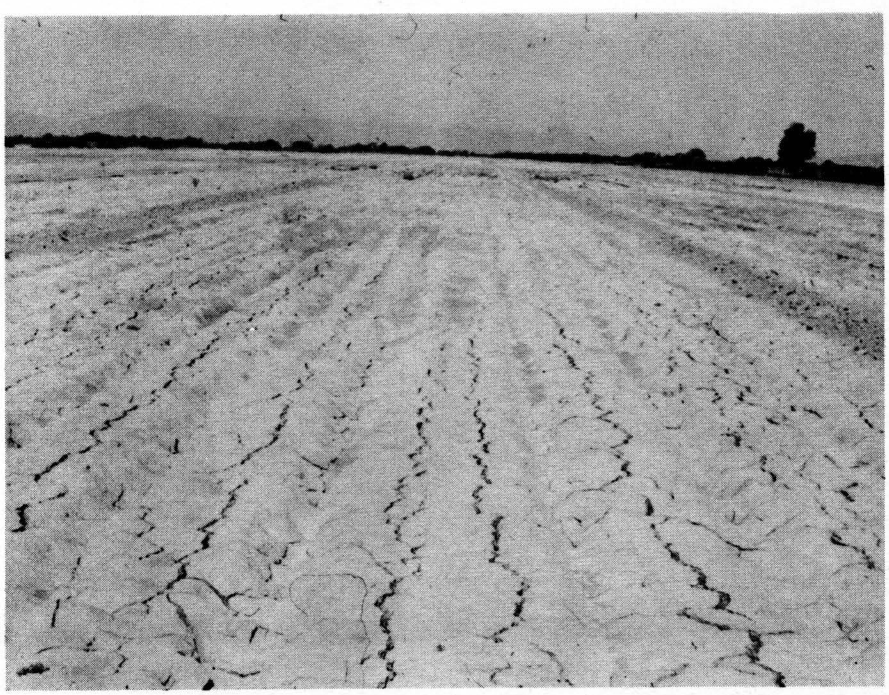


Plate 6. Experimental area after leveling and leaching. Surface cracking and crusting are typical of this soil.

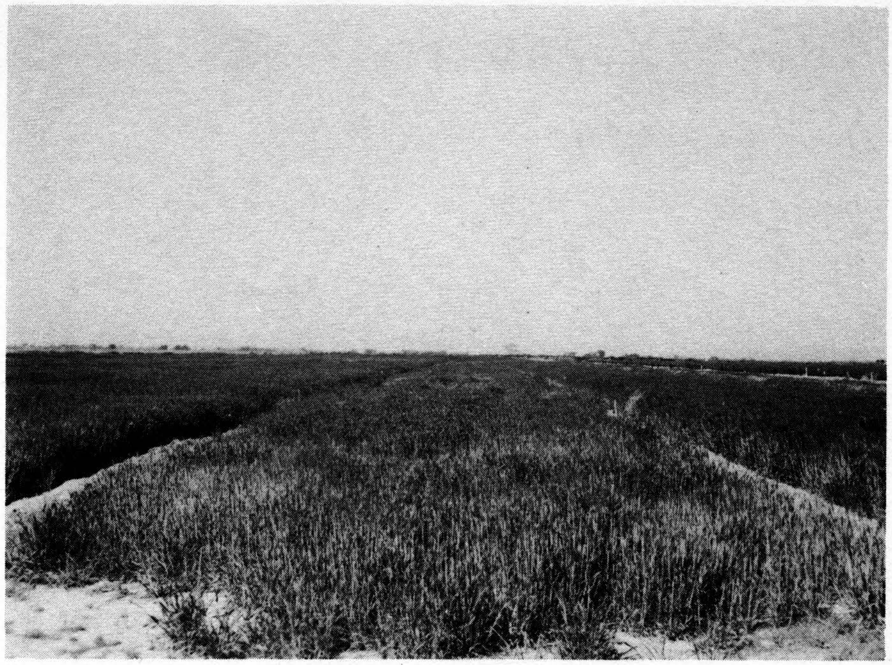


Plate 7. Barley stand, experimental area, 1952-53.
First crop planted after start of experiment.

Plate 8. Sorghum crop 1953 showing good emergence in all plots and illustrating the value of leveling and leaching. Border on left check; middle border 5 tons gypsum per acre; border on right 1 ton gypsum per acre.

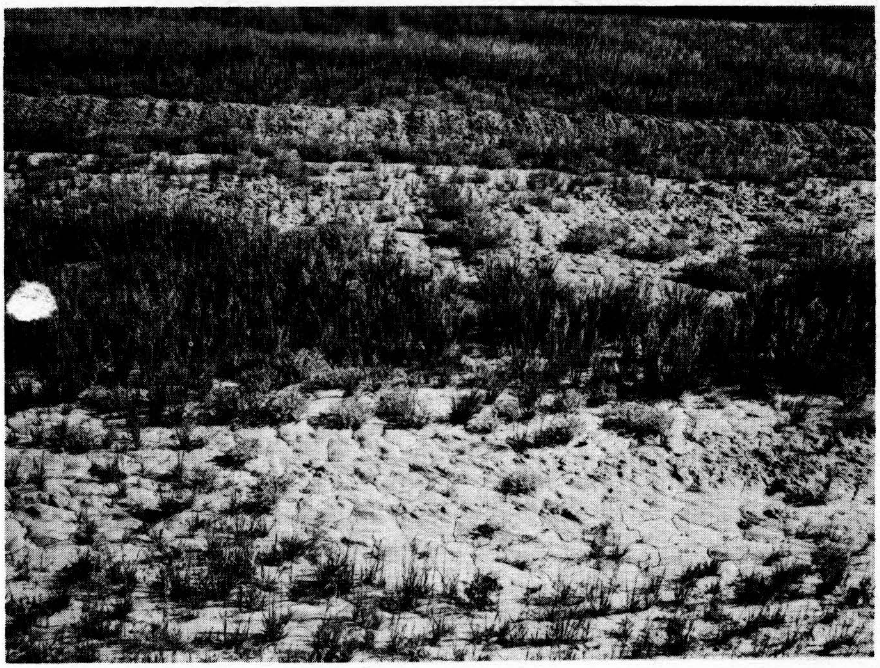


Plate 9. Oat field from which soil samples in table 15 were taken.

Plate 10. Location of area selected for small plot randomized experiment.

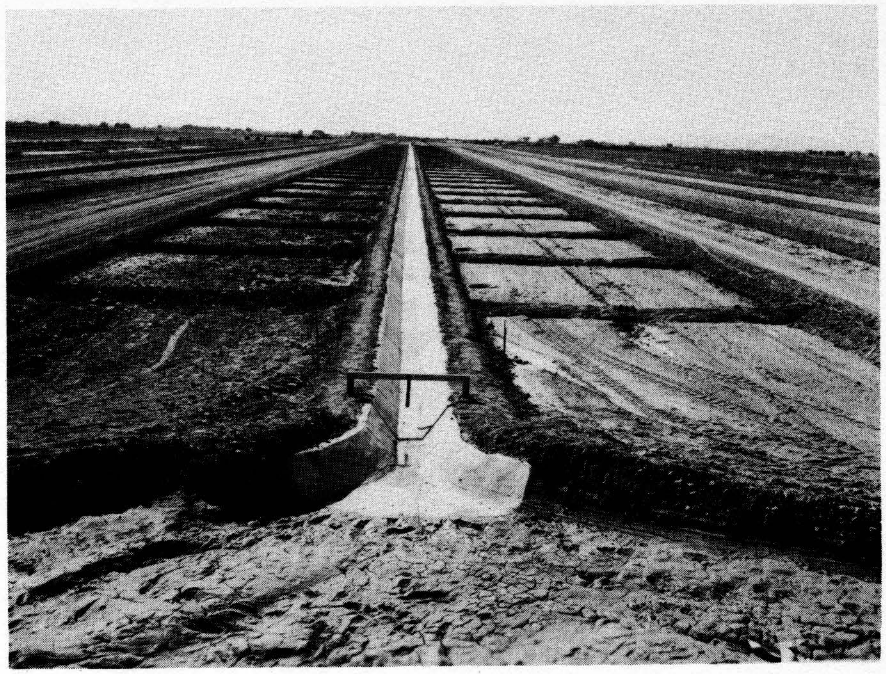


Plate 11. Small plots after pre-irrigation with 5 inches of water. Looking west.

Plate 12. Condition of plots March 24, 1954. Foreground 1 ton gypsum and IBMA treatment in background.

Plate 13. Condition of plots March 24, 1954. Foreground 10 tons manure, next sulfuric acid, third IBMA.

Plate 14. Check plot in replicate D at period of seedling emergence.

Plate 15. IBMA plot in replicate D at period of seedling emergence.

Plate 16. Residual effect of HPAN applied in 1952; sorghum crop 1954. Right check, left HPAN.

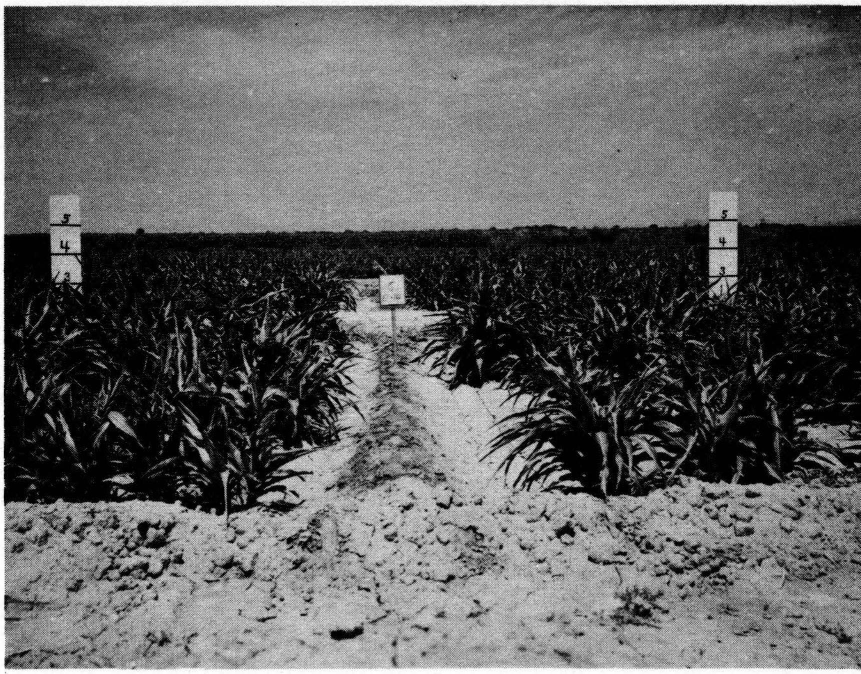


Plate 17. Left IBMA plot; right, sulfuric acid plot; C replicate 1954 sorghum crop.

Plate 18. Close-up of rough tillage plot, replicate A.

Plate 19. Close-up of rough tillage plot, replicate A, after planting and 2 irrigations. Seedling emergence only in cracks.

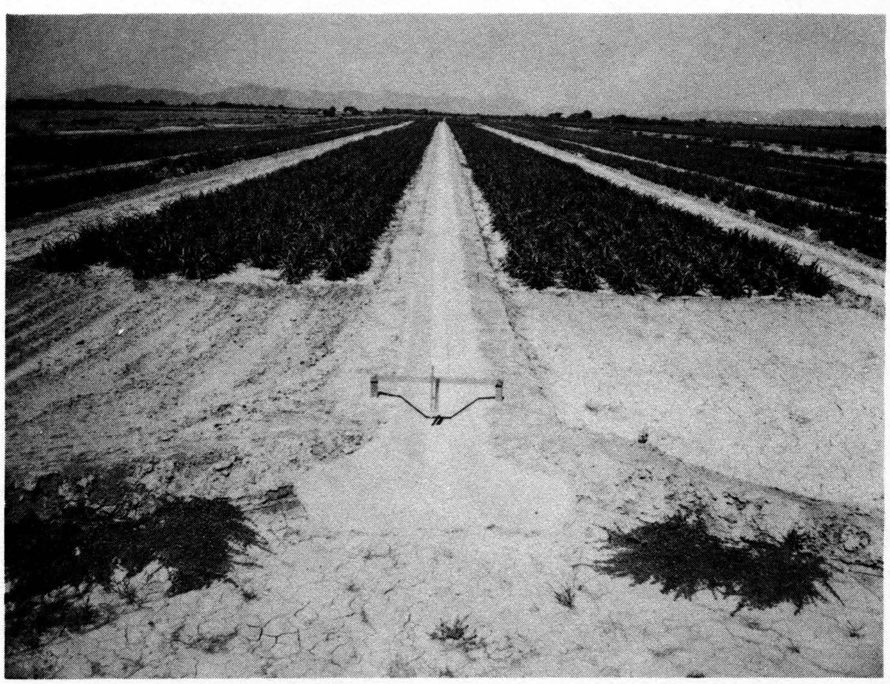


Plate 20. 1954 sorghum crop showing effective reclamation.

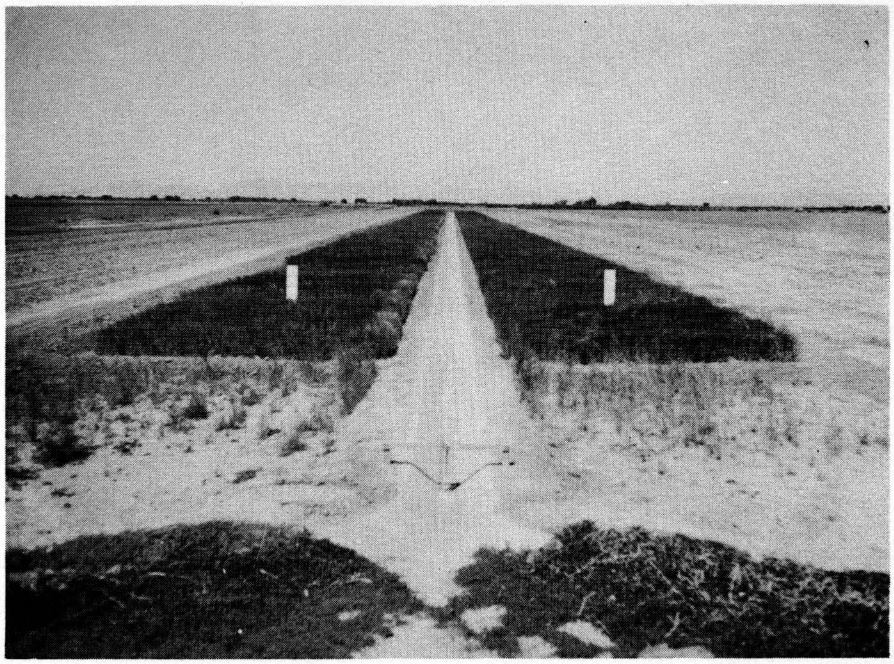


Plate 21. 1954-55 barley crop showing effective reclamation.

Plate 22. Orzan plot, replicate D.

Plate 23. Orzan plot after 6 inch irrigation: A, check; B, 1000 lbs. orzan per acre; C, 1 ton orzan per acre; D, 1 ton gypsum plus 1000 lbs. orzan per acre.

Plate 24. Same as plate 22 and 23 after a second 6 inch irrigation.

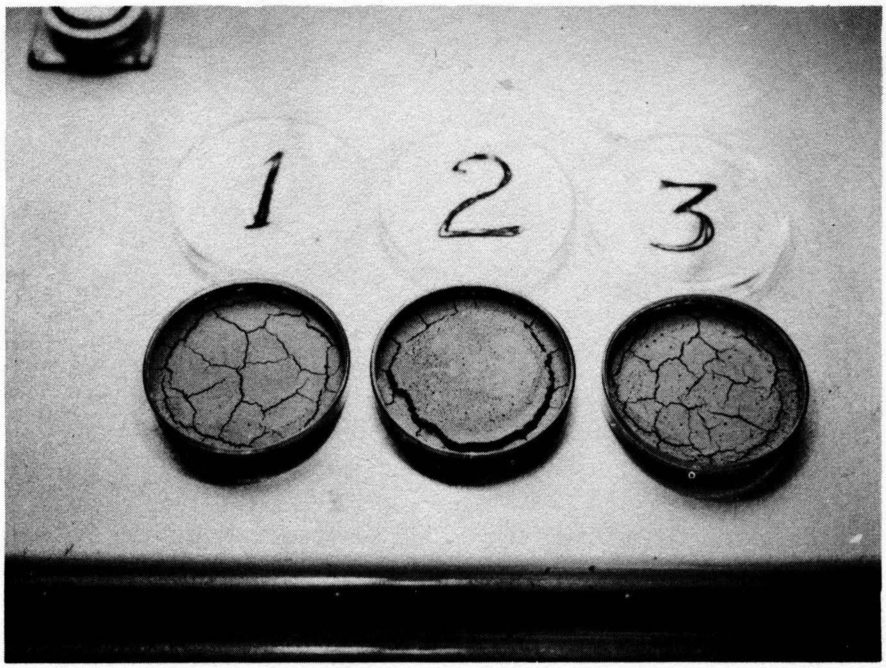


Plate 25. Cracking of Gilbert soil: 1, leached with normal ammonium acetate then with saturated gypsum solution, replaceable K 0.5 m.e./100 gms.; 2, Desalinized by leaching with water, replaceable K 4.7 m.e./100 gms.; 3, desalinized by leaching with saturated gypsum solution, replaceable K 2.8 m.e./100 gms..